"Explore business models and operations of start-up companies in healthcare"

by

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Biographic note

Nuno Terra was born in Porto, Portugal in 1977. He is a graduate in Mechanical Engineering from ISEP (Instituto Superior de Engenharia do Porto) and has developed his professional activity in Industry in areas such as Logistics, Production and R&D.

Following his growing interest in the areas of Economics and Management and the need to acquire specific training, he has enrolled in the Master in Innovation Economics and Management at FEP (Faculdade de Economia da Universidade do Porto) with a dissertation entitled “Explore business models and operations of start-up companies in healthcare”.

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Resumo

No atual contexto económico global, as start-ups têm assumido um papel de relevo, especialmente no último quarto de século. Algumas delas têm conseguido crescer significativamente e de forma muito rápida com base num paradigma que alia inovação e tecnologias disruptivas para criar novos mercados. Este tipo de empresas atraiu a atenção não só dos grandes investidores que procuram obter um retorno significativo, mas também de inúmeros Estados, que com o seu apoio pretendem alavancar a criação de emprego e o crescimento económico.

As Universidades têm tido um papel importante neste processo pois as start-ups são uma das maneiras de monetizar o seu investimento em I&D, ao mesmo tempo que servem de ponte entre o conhecimento e a economia real.

Esta dissertação ambiciona encontrar ligações entre o modelo de negócio e a cadeia de abastecimento procurando resposta à seguinte questão de investigação: "Qual a ligação entre o modelo de negócio e a cadeia de abastecimento em empresas start-up na área da saúde?" através da descoberta de como estes dois importantes elementos na criação de start-ups se articulam entre si. Esse objetivo foi alcançado através de um estudo exploratório usando como ferramenta um caso de estudo múltiplo de cinco start-ups incubadas na Universidade do Porto, todas elas a operarem na área da saúde. A ligação foi confirmada usando o modelo produto-mercado-cadeia de abastecimento, resultando na introdução de uma nova ferramenta que permite uma articulação dinâmica entre o modelo de negócio e a cadeia de abastecimento. Por fim, foi discutido o conjunto de limitações deste processo que poderão conduzir a investigação futura.

Palavras-chave: Modelo de negócio, cadeia de abastecimento, modelo produto-mercado-cadeia de abastecimento

Abstract

Start-up companies have been a major player in global economics for the past quarter century. Many of the recent business giants have emerged from start-ups based on innovation and disruptive technology that create new markets. This kind of venture has caught the attention not only from private investors who expect to have huge returns but also from governments all over the world, who see these start-ups as a driver for employment and economic growth.

Academia has also embraced this phenomena and foster start-up creation as a way to connect Universities with the real economy by building bridges between knowledge and real-life application and a way to monetize their R&D.

This dissertation seeks to find a connection between business models and supply chain in start-ups by answering the following research question "What is the linkage between business model and supply chain in healthcare companies?" and trying to find out how these two important elements for start-up companies are articulated. This was accomplished by means of an exploratory research to a multiple-case study of five start-ups incubated in the University of Porto, all of them operating in the healthcare sector. The linkage was confirmed by using the product-market-supply chain framework, leading to the introduction of a new tool allowing for the business model to be dynamically articulated with the supply chain. Finally, the discussion of the set of limitations of this research has produced a number of avenues for future research.

Keywords: Business model, supply-chain, product- market- supply chain framework

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List of abbreviations

BMC – Business Model Canvas

CEO – Chief Executive Officer

DWV^3 – Duration of life cycle, Time window for delivery, Volume, Variety, Variability

EU – European Union

FEP – Faculdade de Economia da Universidade do Porto

FMS – Flexible Manufacturing System

I&D – Investigação e Desenvolvimento

IEEE – Institute of Electrical and Electronics Engineers

INESC TEC – Institute for Systems and Computer Engineering, Technology and Transfer

IP – Intellectual Property

JIT – Just in time

MM – Mixed mode

MRP – Manufacturing resource planning

MTO – Make-to-order

MTS – Make-to-stock

OEM- Original equipment manufacturer

OQ – Order qualifiers

OW – Order winner

PR – Public Relations

PLC – Product life cycle

PMSC - Product-market-supply chain

R&D – Research and Development

SCC – Supply Chain Canvas

SME – Small medium enterprises

TPS – Toyota Production System

TTO – Technology Transfer Office

UP – Universidade do Porto

UPTEC – Parque de Ciência e Tecnologia da Universidade do Porto

1. Introduction

The overall purpose of this dissertation is to explore a linkage between the business model and the supply chain in university spin-offs that evolved to start-ups in the area of healthcare. This was addressed with a multiple-case study of five start-ups born and incubated in Universidade do Porto (UP). From the collected data resulted an analysis that relates the importance of the business model and supply chain and of the articulation between them.

Although the thematic of business models and supply chains has been thoroughly explored, the study of both areas has always been done separately and the majority of the literature that has been produced mainly covers mature companies. As a result, neither a connection has been established between both fields of study nor has an intensive study been done in start-ups, particularly in the supply chain area.

The 2007/2008 global economic crisis has dramatically increased unemployment and bankruptcy among traditional companies as risen. Investors have turned their focus to newborn companies with promising technologies and governments all over the world have created specific programs to foster the growth of these ventures. While facing uncertainty, a significantly part of the unemployed population has turned their hopes to entrepreneurship, while many young graduates from Universities prefer either to create their own companies or to accept the challenge and the fulfillment of building disruptive business models in University spin-offs. This last group has also played an important role because the visibility that is given to start-ups and the institutional context of support has led them to create their own start-ups, mainly for two factors: first, their will to monetize their efforts, translated in several years of study and research that sometimes assumed an ethereal nature; and second, due to the difficulties of selling products or services via the University, because of its public and non-lucrative essence, making it preferably to license technology from the institution, allowing for a process of growth and scalability of the company.

Portugal is no exception to the start-up hype and the numbers speak for themselves (Informa D&B, 2015):

- Start-ups represent only 6,5% of the economic fabric yet they are responsible for 18% of the total of new jobs created.
- Between 2007 and 2013, a total of 271430 new ventures were created, ascending to an average of 35000 in 2013 and 2014, the highest value since the beginning of the crisis in 2007.
- In 2013, 65% of all start-ups created survived their first year, the highest value since 2008.
- The number of exporting start-ups has grown to 10% in 2013 from 8% in 2008.
- Exports are responsible for 50% of the business volume and its weight has grown to 67%, reaching a maximum since 2007.
- The Northern part of the country is responsible for the birth of 36,3% of all the new companies in this period.

The University of Porto is at the very core of the Northern part of the country and being one of the most active higher education institutions in Portugal, obviously has acted as a major contributor to the national University spin-off environment (Universidade do Porto, 2015):

- 183 national and international active patents.
- 20 active licensed patents.
- 258 communications of invention.
- 203 companies hosted in the University of Porto incubator UPTEC (Parque de Ciência e Tecnologia da Universidade do Porto).
- 1832 jobs created in incubated start-ups.

The design and evolution of the business model has been a core subject when dealing with start-ups. The complexity of the market and the bureaucratic process of funding challenges made it essential for their birth and sustainability. In the academic entrepreneurship environment of UP, Osterwalder et al. (2010) Business Model Canvas (BMC) has been the unofficial tool adopted to this purpose. This investigative process aims at shedding some light over its relation with Barros et al. (2012) construct of supply chain design, resulting in Tedim et al. (2016) new approach in the form of a product-market- supply chain framework, tested in the healthcare start-up sector.

2. Literature review

Our knowledge system is based in the theories and studies of all the greatest minds that have ever lived in human history, from Aristoteles to Newton, so basing one's studies in our collective cognition is not only a way to respectfully honor our ancestor's work with a scientific approach but to be certain the best way to build the future is learning from the past (Webster, 2002). For such, a review is conducted. A literature review cannot adopt the form of a standardized compilation of quotes and citations, much like a massive phone book, yet it should be structured as the backbone from which questions, constructs and results will give forth (Bem, 1995).

This section aims at reviewing the literature of both proposed fields of study: Business model and Supply chain.

The approach chosen to study both fields in healthcare start-up companies can be summarized by a quote of Wallbank (1981), wrongly attributed to Charles Darwin's *On the Origin of Species by Means of Natural Selection* (Darwin, 1859):

> "*In the struggle for survival, the fittest win out at the expense of their rivals because they succeed in adapting themselves best to their environment."*

In nature, change is therefore a necessary condition for survival in an aggressive environment which requires constant adapting to natural events such as weather conditions, famine and predators.

Start-up companies face similar conditions from an early stage as spin-offs untill they reach maturity. Their growth, but essentially their survival, is directly associated to their attitude towards changing their business models and supply chains in an environment of uncertainty and turbulence, either by experimentation (Murray & Tripsas, 2004), planning (Dew, Read, & Sarasvathy, 2006) or by a combination of both (Ries, 2011).

2.1 Basic concepts

First, it is important to review some basic concepts that will accompany us throughout this dissertation.

2.1.1 Business model concept

The term "Business model" has been a mundane expression for years, although its first reference goes back to the late 1950's (Bellman, Clark, Malcolm, Craft & Ricciardi, 1957). The concept has evolved, which is visible by the numerous definitions of several authors:

- "An architecture for product, service and information flows, including a description of the various business actors and their roles; and a description of the potential benefits for the various business actors; and a description of the sources of revenue." (Timmers, 1999)
- "A loose conception of how a company does business and generates revenue" (Porter, 2001)
- "A business model can be conceptualized as a system that is made up of components, linkages between components, and dynamics." (Afuah and Tucci, 2001)
- "A description of the roles and relationships among a firm's consumers, customers, allies, and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants." (Weill and Vitale, 2001)
- "Business models specify the relationships between different participants in a commercial venture, the benefits and costs to each and the flow of revenue. Business strategies specify how a business model can be applied to a market to differentiate the firm from its competitors." (Elliot, 2002)

2.1.2 Spin-off concept

A spin-off is generally understood as a "new company that is formed (1) by individuals who were former employees of a parent organization, and (2) a core technology that is transferred from the parent organization." (Steffensen et al., 2000). But spin-offs don't always emerge from existing companies, there is an increasing trend in academic or university spin-offs. They are the result of the need for an appropriate vehicle to bridge the knowledge created in those institutions and the market needs. Such need has led to the creation of spin-off companies that aim to commercialize disruptive technologies developed in universities. Several authors have their own definition of spin-offs:

- "a university spin-off is defined as a new venture initiated in a university setting and based on technology developed at a university." (Rasmussen, 2011).
- "We define a university start-up/spin-off as a firm which draws upon knowledge that is produced or circulated at the university, in which the founders have met or become associated in the context of a university, and where the business opportunities are an outcome of the university's existing areas of competence in research and teaching." (Bathelt, 2010).
- "…university spin-offs [are defined] as new ventures that are dependent upon licensing or assignment of an institution's IP for initiation." (Wright et al., 2007).
- "…university spin-off [is defined] as a new company founded to exploit a piece of intellectual property created in an academic institution." (Shane, 2004).
- "[University spin-offs are] new firms created to exploit commercially some knowledge, technology or research results developed within a university". (Pirnay et al., 2003).

2.1.3 Supply chain concept

Since the beginning of humanity there have been ways of organization whose purpose was to save time, optimize processes and increase efficiency through specialization but also to develop a business relationship based on trust: the blacksmith would buy iron ore from the miner, the shepherd would buy haylage from the farmer, the shoemaker it's raw materials from the tanner, etc. The first industrial revolution has increased the need of specialized suppliers but the first scientific approach to study this question was made in the 20th century by Taylor (1911), in an effort to transform business management in an objective science by means of raising operational efficiency. Further research was made throughout the 1940's and 1950's, first to find ways to improve military logistics during World War II, and later to improve businesses in the post-war economic boom.

The "Supply chain" has since been an important field of study in business management by many authors. Some of its definitions are as follows:

- "A network of firms interacting to deliver product or service to the end customer, linking flows from raw material supply to final delivery." (Ellram, 1991)
- "Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers." (Lee and Billington,1992)
- "The set of entities, including suppliers, logistics services providers, manufacturers, distributors and resellers, through which materials, products and information flow." (Kopczak, 1997)
- "Supply chain management encompasses materials/supply management from the supply of basic raw materials to final product (and possible recycling and re-use). Supply chain management focuses on how firms utilize their suppliers' processes, technology and capability to enhance competitive advantage." (Tan et al., 1998)

2.2 Business model literature

The importance of the business model as a tool to leverage competitive advantage has been object of intensive research, confirming that it undoubtedly contributes to the survival and performance of companies that exist in "turbulent industries" (George et al., 2011). An interesting aspect of the business model is that it may even create value by spillover effect in discovery-driven research, paving a way for new strategies not accounted in traditional business models. Chesbrough (2007) even emphasizes that "a better business model often will beat a better idea or technology". Another extent of the business model, besides a channel through which companies monetize their technologies, is its ability to increase and promote innovation as it gives a global view of the challenges to be tackled within the organization regarding the organizational structure, process (supply chain, for example) and product (Zott et al., 2011). The choice of the correct business model may dictate their long-term survival, even if all other necessary success factors such as talent, ideas and opportunities are gathered (Zott et al., 2007). Factors like dynamic markets, ferocious competition and product restrictions due to demanding certifications are external sources of uncertainty companies also have to deal with.

2.2.1 Business Model Canvas

The business model's target is to explore the relation between efficiency and the installed infrastructure and between the creation of value and customers' needs. The company's competitive advantage can be leveraged by examining a set of internal and external dimensions (Osterwalder et al., 2010).

An effective business model is one that provides us with a clarification of fundamental aspects within the companies' structure and the relations within itself and beyond its borders. The importance of identifying those "building blocks" and to display them in a graphic representation that is "reasonably simple, logical, measurable, comprehensive, and operationally meaningful" (Morris et al., 2005: 729), led Osterwalder et al. (2010) to create a translational language that would normalize a reference model, making it simple

to understand while offering a complete overview. That framework is the Business Model Canvas:

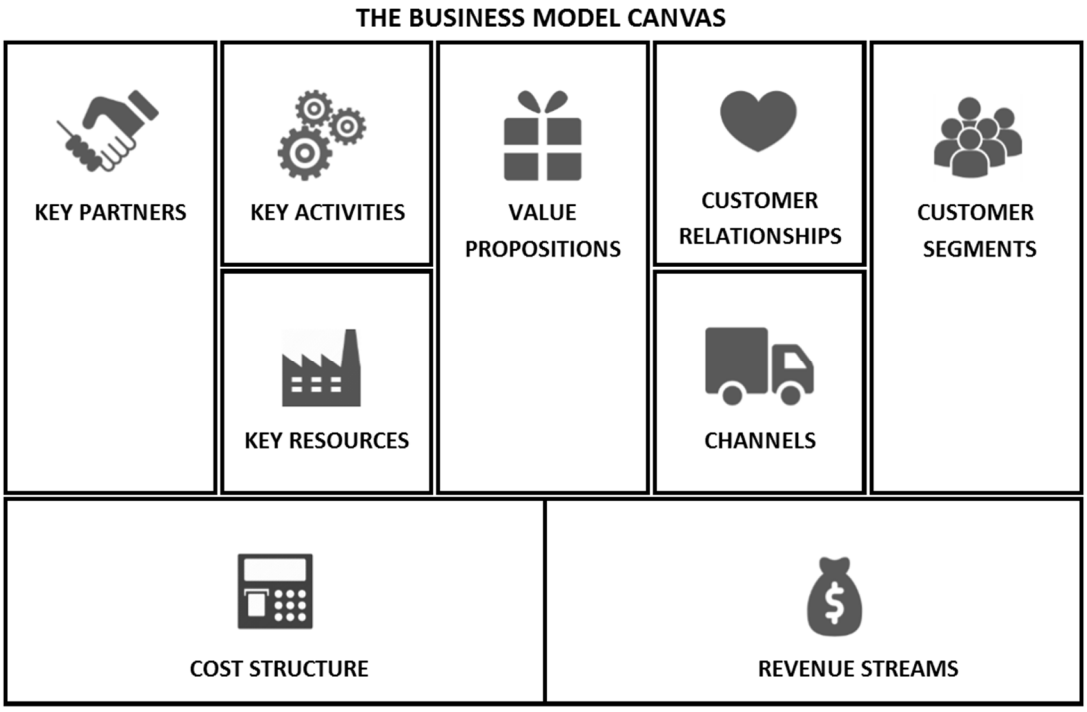

Figure 1 – Business Model Canvas

Source: adapted from Osterwalder et al. (2010). Business Model Generation: A Handbook for Visionaries

According to the above Business Model Canvas framework representation, Osterwalder et al. (2010) defined the "building blocks" as follows:

- Customer Segments: categorization of the different targets (people and/or companies) that will become clients. Several criteria may be used such as gender, spending patterns, age, socio-economic group, location, niche or mass market, diversification, etc.
- Value Proposition: definition of the value created from products and/or services for the correspondent Customer Segment. The usual criteria are newness, performance, customization, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility and convenience/usability.

- Channels: definition of how the value created will be communicated and how the product or service will be delivered to each Customer Segment. Several criteria can be used such as own, partner or mixed channels.
- Customer Relationships: definition of the relationship channels between the companies and their Customer Segments with personal assistance, self-service/automated service, communities and co-creation as the most common criteria.
- Revenue Streams: definition of how the company generates cashflow.
- Key resources: description of the main assets companies possess to effectively create and deliver value such as human, financial, physical and intellectual.
- Key activities: definition of the main actions companies perform to effectively create and deliver value. The usual criteria used are production, supply-chain management, R&D, problem-solving, sales and platform/network.
- Key partnerships: definition of the main relations companies establish with external partners to effectively create and deliver value. The usual criteria used are strategic alliance (non-competitors), strategic partnership (competitors), joint-venture, buyer-supplier relationship, etc.
- Cost structure: description of the costs inherent to the companies' activities. The Revenue Streams minus the Cost Structure will, roughly, deliver the earnings of the company

2.2.2 Entrepreneurship and business models

Although the linkage between business models and entrepreneurship has been a recent development (Trimi el al, 2012), both have been studied separately for some time as distinct subjects of strategic management. Chesbrough et al. (2002) established a direct relation between an adequate business model and the grasp of revenue, as the connection needed for start-ups successfully bringing technology to market. Customer oriented business models affect the performance positively while lack of change in the early adopted business model may affect the longevity of the company.

Kaplan et al. (2009) concluded, through the study of 50 companies backed by venture capital, that business models were of extreme importance for building a solid foundation in start-up companies. By defining their business models at a very early stage, start-ups were able to define a clear path to their growth and sustainability in harsh seas, with management assuming a key role in designing and evolving business models as this was also proved to be essential for long-term survival. The authors also ascertained that bio-tech start-ups are always more focused on their business scope than every other new venture. In fact, it is important to understand that stability plays a key role in start-up companies not only at their birth but also after the early stages and the business model is a tool for "establishing the DNA of the firm" (Schindehutte et al., 2008). Although difficult, establishing a business model at the beginning of the venture is as crucial as its adaptation (Andries et al., 2007) because experience will provide for a deeper knowledge of the market.

Morris et al. (2005) studied the link between business models and performance and concluded that designing an inadequate business model is one of the reasons for failure despite a positive context resulting of the combination of talent, resources and business ideas. The continuous adaption via experimentation proved to be the sustainable path. This was confirmed by Andries et al. (2013) by determining that experimentation driven business models would endure a start-up's long-term survival despite a slow start, contrary to a focused commitment approach that would return faster results in the beginning but would menace the long-term.

Willemstein et al. (2007) studied the dynamics of Dutch bio-techs and found that their business models seemed to evolve from a single to multiple products type, in an attempt for firms to monetize on their R&D efforts by offering the market various products and combinations, while opening a window for out-licensing technology.

2.2.3 The role of Universities: the spin-off

Universities have long been both the source and the repository of tangible human knowledge. Yet, step-by-step, their nature is becoming less of a "conservator of

knowledge" and more of an "originator and exploiter of knowledge for local economic development" (Harrison et al., 2010). Their role as "engines of economic growth through [university] spin-off company formation" (Shane, 2004) is the reason behind the increasing expenditure in Government initiatives to promote technology based innovation and entrepreneurship. Shane (2004) claims that the monetization of knowledge can be pursued in several ways, with spin-offs as the academic entrepreneurship version of start-ups assuming the role of transforming Intellectual Property (IP) generated in academia in prosperous business ventures in five ways:

- Source of economic development by promoting investment on university IP and returning prosperity at local level by generating income and jobs.
- Serving as a vessel to help academic knowledge to cross the border and being effectively commercialized.
- Supporting universities in their mission to transmit knowledge by funding research and helping more teachers and students to be admitted.
- Creating companies that are known to have good performance.
- Promoting a more effective and profitable way of generating income for the university rather than licensing technology to long-standing companies.

Shane (2004) also ascertained that the process of creation of spin-off companies spans over the next five stages through two actions [further R&D (Research and Development) investment and market research]:

- transform knowledge in the form of government research into a

- tool that addresses market needs by the creation of a product or service.

- secure IP through patent and industrial design applications prior to the

- market development stage, clearly defining target segmentation

- licensing the research through the University's Technology Transfer Office.

On the contrary, Wright et al. (2007) argue that spin-offs develop under five different stages:

- Research.
- “Opportunity-framing”.
- Organization before commercialization
- Reorientation.
- Viable income.

For Rasmussen (2011), the above linear models are way too simplistic to explain such a highly irregular process due to its complexity and rather prefers the use of “process theories” exploring each aspect in the development of spin-offs, using Van de Ven et al. (1995) four process change theories (life cycle, teleology, dialectic and evolutionary).

While being based on disruptive technology, spin-offs may need massive funding due to technical and market aspects, with Shane (2004) found a positive correlation between these three factors, which in turn highlights the importance of a having good financial basis for these companies to evolve. These findings and also the lack of human capital were also confirmed by Wright et al. (2007). Van Geenhuizen et al. (2009) go a step further by explaining that market constraints are more important to spin-off companies than, respectively, financial and management constraints. Their research shows that lack of market knowledge, low investment in marketing and sales, lack of sound financial structure and management skills are often the reasons spin-offs fail.

2.2.4 Business models in spin-offs

Although literature combining business models and spin-offs is scarce, some studies have explored these relations in the creation of business ventures from university knowledge. For instances, Bower (2003) observed that most spin-offs founders have developed their professional activities in academia which brings added difficulties in contrast to founders with corporation background, as critical decisions have to be made and sometimes market demands are not fully understood due to inexperience. In fact, it’s crucial to have a close relation with investors that can bring their experienced views to enhance technical and financial skills as the market evolves and therefore have a dynamic approach to the business model in order to provide a faster response to obstacles.

A study carried out at Cambridge university by Druilhe et al. (2004) argued that change occurs in business models at the pace that founders of new ventures gain in-depth knowledge of the market and of the companies' own resources. This maturity is the result of "an iterative, non-linear process" (Druilhe et al., 2004), as relationships grow closer with all other actors (investors, customers, suppliers, etc.).

Heirman et al. (2004) observed that less experienced entrepreneurs tend to underlie on a long-term income strategy, built on massive financial support, while more experienced ones try to achieve a rapid independence from venture capital by basing their growth in more dynamic and active business models. The authors also claim that university spin-offs are different in their essence from company ones because they are heavily based on their disruptive technology rather than on the market, as a result of their origin in academia, their link to universities and to the correspondent Technology Transfer Office (TTO).

The approach to the design of the business model led Wright et al. (2007) to identify three different types of university spin-offs:

- Spin-offs built by venture capital, who engage with their financial supporters for a sustainable growth rather than short-term revenue through rapid commercialization of their products or services.
- Lifestyle spin-offs, that focus on market demand for an earlier break-even and develop a low-cost, fast time-to-market approach.
- Prospector spin-offs, a combination of the above as they mix acceptance by holders and the definition of their business models at the same time.

Sanz-Velasco et al. (2008) observed in their study of eight university spin-offs that the way these companies gain maturity through the acquisition of knowledge is distributed in two ways as evidenced by the table below:

Learning based on experience	*Learning based on external relations*
Market scanning	Adding new employees
Virtual market experimentation	Obtaining external expert advice
Interaction with existing customers	Participation in entrepreneurial education programmes
Interaction with new customers with new requirements	
Imitation	
Responding to external changes	

Table 1– Categorization of learning types in spin-off companies

Source: adapted from Sanz Velasco et al. (2008): Entrepreneurial learning in academic spin-offs: a business model perspective.

They also concluded that spin-offs that are created in a more protective atmosphere are less prone to evolve using trial and error, or as previously mentioned, experimentation, because of the added experience of the actors that support them, such as venture capitalists, incubators, etc.

In comparison to traditional business model literature, Doganova et al. (2009) observed that spin-offs have a dynamic fruition as their traditional counterparts, allowing for an adaptive approach based on scenario adoption as well as rapid change due to the need of rapid market response, while evolving with the learning provided by partnerships.

Finally, Munari et al. (2011) found that the type of business model a spin-off uses to structure itself is directly correlated with the type of investment received: private venture capital investors prefer to invest in technology-based business model and service-based business models are often financed by publicly-supported ones.

2.3 Supply chain literature

Access to information has been democratized by the internet and consumers are now more literate, more aware of what the market has to offer and more capable of making assertive choices about the products that better serve their needs. This has led to a revolution in the relationship between consumers and companies, not only to web-based companies but also for more traditional companies. In fact, the multitude of products available and the growing need of customization by the consumer would deem unsuccessful Henry Ford's "You can have any color as long as it's black." (1922) product strategy, because focus has changed from the supply chain to the consumer. As Fuller et al. (1993) put it, companies must adapt from being "supply-centric" to "customer-centric" by building their supply chain "from the customer backwards" instead of "from the factory outwards" in order to satisfy the increased demand of customized products. Companies can no longer build on a rigid, more convenient and effective supply chain but instead, due to this new dynamic, their response increases the complexity of it by matching "the design of their supply chains to product and market characteristics" (Fisher, 1997) while keeping it "lean" and "agile" or "leagile"- a combination of both (Naylor et.al., 1999).

2.3.1 Competitive differentiators

During a product's life cycle, there are several key dimensions to be considered that add to a company's competitive advantage (Childerhouse et al., 2002; Claro et al., 2012) and allow for a bigger differentiation in the market, being forced by both consumers and competition to move away from a "one size fits all" philosophy (Shewchuck, 1998):

- Design capability
- Design lead time
- Cost
- Quality
- Lead time
- Service level
- Reliability

While expanding their knowledge on supply chain design, Childerhouse et al. (2002) observed that the contribution of these competitive differentiators assumed different values throughout the whole product life cycle stages - introduction, growth, saturation, maturity and decline. In fact, their findings were later consolidated by Aitken et al. (2005) who also used the lightning business to observe generic similarities with other industries. The articulation between Order Winners (OW – the set of characteristics that a product must achieve in order to be chosen among other candidates), Order Qualifiers (OQ – the set of characteristics a product must achieve in order to be considered by a potential customer as a purchase candidate) and the strategy to be followed at any given stage of the product's life cycle are illustrated in Figure 2:

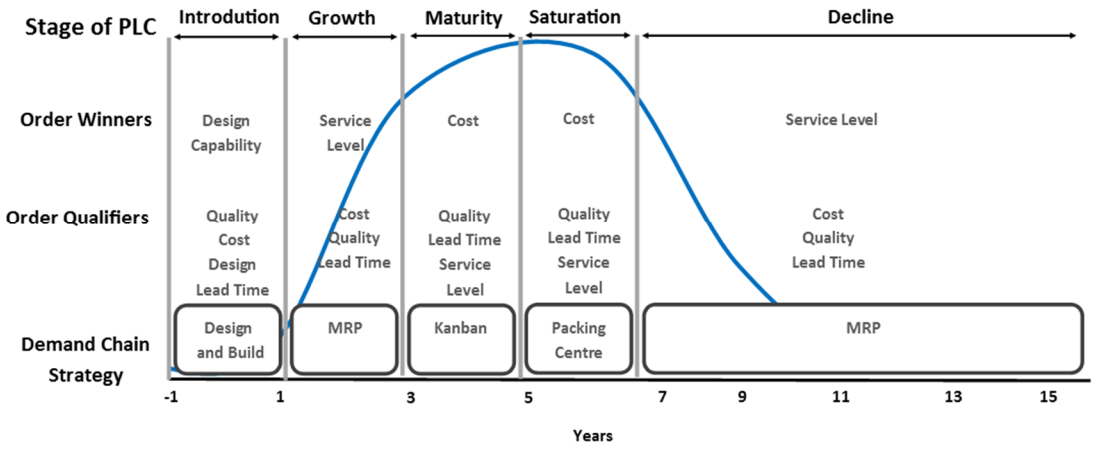

Figure 2 - Change of the OW and MQ characteristics throughout a products life cycle (PLC)
Source: adapted from Childerhouse et al. (2002). Analysis and design of focused demand chains

The design capability assumes the key role as an OW during introduction stage which led Childerhouse et al. (2002) to conclude that a design and build strategy is the most effective at this time.

In the second stage - growth, the product has found its position in the marketplace while demand soars. The key OW becomes the service level has it must overcome an unpredictable demand, causing availability problems. A forecast driven push type Manufacturing Resource Planning (MRP) supply chain is more adequate for this phase.

As the product enters its maturity stage, the key OW changes its focus to cost which is best addressed by a Kanban pull type of supply chain.

The key OW of cost is kept during saturation stage as the company adopts a packing center strategy while production is moved to countries with a lower labor cost to maximize profit.

Finally, when the product reaches the end of its life cycle at the decline stage, to avoid excess stock and end of life losses, the key OW becomes once again service level and the supply chain turns to a forecasted planning MRP type of supply chain.

2.3.2 Demand characteristics

First, it is important to understand Lee's (2002) categorization of products because their market's dynamic will influence how the supply chain strategy will be built according to demand. Products can be categorized as functional or innovative and their characteristics are summarized in the following table:

Functional	***Innovative***
Low demand uncertainties	High demand uncertainties
More predictable demand	Difficult to forecast
Stable demand	Variable demand
Long product life	Short selling season
Low inventory cost	High inventory cost
Low profit margins	High profit margins
Low product variety	High product variety
Higher volume per SKU	Low volumes per SKU
Low stockout cost	High stockout cost
Low obsolescence	High obsolescence

Table 2– Categorization of products according to demand characteristics

Source: adapted from Lee (2002): Aligning supply chain strategies with product uncertainties

Christopher et al. (2000) built the DWV^3 model (Duration of life cycle, Time window for delivery, Volume, Variety, Variability) to demonstrate that there are five basic dimensions that shape the form of the supply chain:

1. Duration of product life cycle: a product's life cycle commonly goes through a pattern curve comprised of the introduction, growth, maturity, saturation and decline phases – although today's business rhythm induces higher uncertainty to this model. For example, short life cycles create the need for rapid time to market by fast-tracking product development, manufacturing and logistics to fulfill a narrow window of opportunity, short end-to-end pipelines to overcome high demand through product life while keeping the cost of lost sales and obsolescence risks low.
2. Time window for delivery: fast selling items such as innovative goods need an accurate delivery interval to answer demand needs which lead to higher competitiveness among suppliers and added pressure to the supply chain members. Functional items may be demanded seasonably and may need a massive production pike for a more wide and exact window for delivery, such as summer watersports or winter ski related products.
3. Volume: it is possible to achieve higher flexibility in production and on the entire supply chain in low volume markets. On the other hand, supplying mass markets aims at taking advantage of economies of scale by using make-to-forecast strategies and lean manufacturing.
4. Variety: an effective and ever going analysis on the number of variations of a product or a product line is required to evaluate the size of stock and the necessity to reduce production because some variants may lose popularity in the decline phase of the life cycle.
5. Variability: although forecasts are of extreme importance, they will often fail due to unpredictability and demand spikes. Undervaluing the first increases obsolescence risk, the later affects the response of the production environment and over-capacity. This, however, may be addressed by having a deeper knowledge of the market by increased forecasting and by an effective reduction of lead-time.

This model was further explored and had practical application in case studies by Childerhouse et al. (2002), Lee (2002) and Aitken et al. (2005).

A supply chain system will naturally be planned to maximize cost efficiency. Yet, today's "shorter and shorter product life cycles" (Lee, 2002) requires the need of a real time assessment of the duration and the stage of the life cycle curve of the product. As a result, the "pressure for dynamically adjusting and adapting a companies supply chain strategy" will certainly increase (Lee, 2002). One of the common examples where this capability is leveraged is the possibility to ship stable demand products directly to the customer without intermediate distribution centers, as it's commonly used by Wal-mart and Costco with their "direct-to-store" strategy (Lee, 2002). By reducing the complexity of the supply chain there is evident cost reduction, although this does not apply to erratic demand products.

2.3.3 Supply characteristics

Products can also be categorized according to the Supply characteristics Lee (2002). The following table sums up the Stable vs Evolving categorization and their unique properties:

Functional	***Innovative***
Less breakdowns	Vulnerable to breakdowns
Stable and higher yelds	Variable and lower yelds
Less quality problems	Potential quality problems
More supply sources	Limited supply sources
Reliable suppliers	Unreliable suppliers
Less process changes	More process changes
Less capacity constraint	Potential capacity constrained
Easier to changeover	Difficult to changeover
Flexible	Inflexible
Dependable lead time	Variable lead time

Table 3– Categorization of products according to supply characteristics

Source: adapted from Lee (2002): Aligning supply chain strategies with product uncertainties

In a globalized economy, it is important to understand the increase of lead-times resulting from the large number of suppliers spread all over the world and multiple pipelines that add pressure to the supply chain management, often asking for ”the ability to manage across diverse cultural, legal and regulatory environments.” (Christopher et al., 2006) This is, of course, a result of a global sourcing of suppliers due to economies of scale which adds risk to the operation and surely an increasing tendency both on the number of suppliers and their reliability but mainly by the extension of lead times.

According to Mason-Jones et al. (2000), there are three basic ways that we can classify manufacturing:

- Lean manufacturing or “Lean thinking” (Womack et al., 1996) is a philosophy that focus on the reduction or elimination of waste and the efficient use of resources, based on the Toyota Production System (TPS). This forecast-driven approach is well known in environments with stable and predictable demand.
- Agile manufacturing has its origins in the Flexible Manufacturing System (FMS) which were later expanded as a concept to supply chain management by Nagel et al. (1991). It is more suitable to an unpredictable and volatile environment where variability is high and flexibility and responsiveness are required for a demand-driven approach.
- Leagile manufacturing is a hybrid approach (Christopher et al., 2000) that brings together both concepts. For example, one can use the lean approach to design a supply chain for functional products and an agile approach for more innovative products. Both can be used at the same time to design a supply chain for a product that combines both innovative and functional (or off the shelf) parts or even to add capability when base demand is overwhelmed by peak demand.

Lee’s (2002) categorization and the three types of manufacturing can be combined, as observed in the following figure:

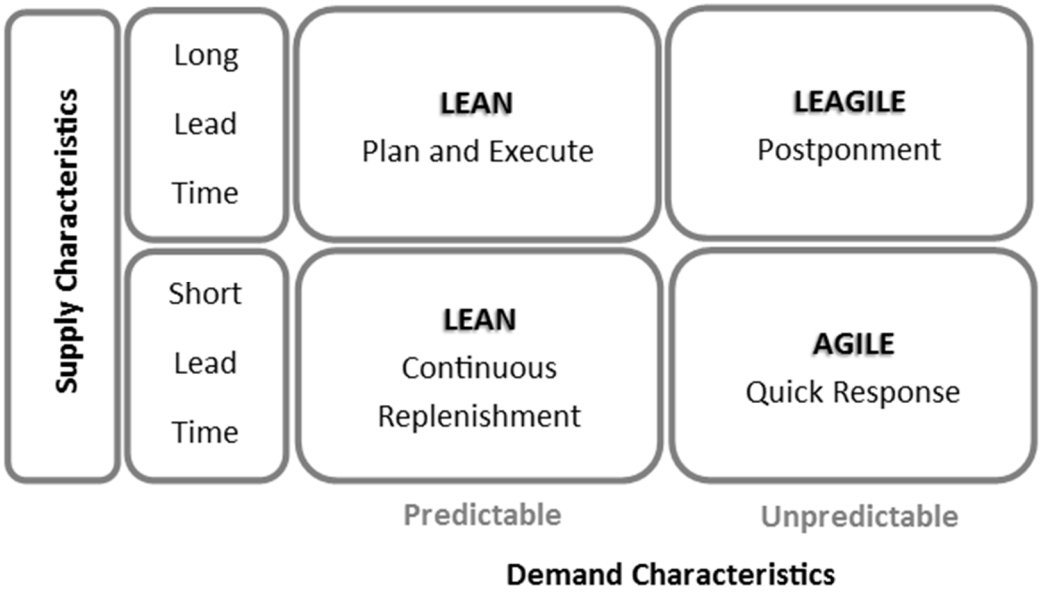

Figure 3 – How demand/supply characteristics determine pipeline selection strategy

Source – adapted from Christopher et al. (2006) - A taxonomy for selecting global supply chain strategies

These combinations provide us four basic supply chain strategies:

- For the combination of a predictable demand and a short lead-time the most assertive option is to use a "continuous replenishment strategy" (Christopher et al., 2006), as used by Procter & Gamble to supply high volume products to Wal-mart.
- For a combination of unpredictable demand and a long lead-time the ideal option is to have a Leagile strategic stock of off-the-shelf products that can be combined and assembled together whenever they are demanded, which is the actual strategy followed by Hewlett Packard for their printers.
- For a combination of predictable demand and long lead-times, a lean option is the most efficient approach, relying on forecast and planning ahead, much as any other retailer like Woolworths would do.
- For a combination of unpredictable demand and short lead-times, the option for agile strategies is the most appropriate solution. For example, Zara uses this system to address peaks with a fast response by managing the end-to-end process on their suppliers for added flexibility and having a logistics operation that can transport their products in a relatively fast way across Europe.

2.3.3 Sourcing strategy

A resilient supply chain is a very important tool for start-up companies because it enables them to react rapidly and effectively to uncertainty and to diminish their vulnerabilities against ever changing, disruptive and complex markets.

Burke et al. (2007) have explored the strengths and weaknesses of having a single or multiple sourcing strategy:

- A single supplier strategy based on higher volumes will positively affect profit margins by reducing lead-times, inventories, sourcing, processing and inspection costs and building a long-term partnership. On the other side, there is an added risk of depending on a single supplier and a gradual reduction of bargaining power. This strategy is usually found in JIT (just-in-time) supply chains.
- A multiple supplier strategy is better adapted for strategic items in today's uncertainty environment via a flexible and competitive approach which protect the buyer during shortage or emergency by having back-up sources, keeping the buyers bargaining power by means of bigger competition and lower complacency and by having low indirect costs.

When building a supply chain there is also the choice of adopting a local vs. global supply chain strategy (PrasannaVenkatesan et al., 2012; Albino et al., 2002):

- A local supply chain strategy will benefit the community by creating wealth and jobs which in turn act as a form of campaign for the companies' Public Relations (PR). Quality control is simplified because the suppliers are placed close to the company and it becomes easier to procure specialized products adapted to local preferences. Lower costs and shorter lead-times are a consequence of the higher stability and predictability. On the other hand, sometimes local suppliers are less efficient Small and Medium Enterprises (SME) with high resistance to change, unable to achieve economies of scale and become very dependent on a sole buyer, leading to complacency issues and bad PR by the end of the supply contract.

- A global supply chain strategy is chosen whenever a company is looking for cost reduction, specific skills or resources that are not available locally, building a multiple supplier strategy and choosing to make a global presence in an efficient way. Yet, such choice must take into account barriers such as cultural differences, less efficient control of production, multiple time zones, risks associated to emerging economies such as financial, political and labour issues that may interrupt the supply chain and losses of intellectual property and business secrecy.

2.3.4 Supply chain relationships

The purpose of strategic partnerships is reducing duplicated tasks and cost saving (Herbig et al, 1994) and they can endure for a long time by sharing goals, benefits and risks a (Mentzer et al., 2000), becoming a source of competitive advantage if all players successfully manage product and information flows.
Buyers and suppliers will gain obvious advantages if they focus on their individual core competences and capabilities:

- Suppliers earn reputation, gain access to new technologies and information, develop their operations and gain stability in unstable markets (Anderson et al., 1991; Fram et al., 1993).
- Buyers will establish technical cooperation with the aim of reducing purchase costs, improving their profitability, reducing risk and increasing flexibility (Ailawadi et al., 1999).

For a supplier to become an Original Equipment Manufacturer (OEM), it is important that the commitment of both parties to establish strong bonds based on trust is built on top of a contractual basis. Several tools may facilitate those strong bonds such as planning, joint operation controls, communications, risk and reward sharing, clear scope, joint investment of both parties (machinery, software, etc.) and careful planning (Lambert et al., 2004).

Another type of relationship that creates strong bonds is Supply chain integration. It can assume the form of a traditional "pure market logic, adversarial price-based" operational integration (Saccani et al., 2004) or a more advanced technological "design of the exchanged part or the final product" form (De Maio et al., 1992). Bensaou et al. (2005) divides such integration in three forms:

- "high integration on logistic aspects, low or no integration on design", usually referred as aJIT (Jst-in-time) integration.
- an Agreement of "technological integration, focused on product design/redesign".
- or an Evolved Partnership with "high integration on both areas".

This integration will rely heavily on the information sharing needs and capabilities between both parties (Bensaou et al., 1995) but will obviously assume different types according to the buyer-supplier relationships between traditional remote type, control type (according to the buyers control parameters), interdependence (technical parts with need of investments and active information swap), structural (when a reduced number of suppliers and a narrow market when buying a complex product imply huge investments in both control and structural mechanisms) or a mutual adjustment partnership (high-tech or innovative state-of-the-art products that imply the higher levels of trust in a supplier-driven type of relationship).

Finally, the partnership thematic is not problem free (Ellram, 1995). Non-healthy dependencies can be created by the buyer by imposing price reductions due to high dependence or by the supplier for the buyer's loss of bargaining power. Cultural values and differences may cause poor communication and compatibility. Lack of managerial support and quality commitment by the supplier's administration or resistance to share information by the buyer will cause a gap in trust.

2.3.5 Production environment

The supply chain development is directly derived from the type of product (variety, complexity, etc.), the available manufacturing capacity and the demand rates. These factors will influence the choice between lot sizes and production environments from the three types listed below:

- Make-to-order (MTO) manufacturing uses a pull-type supply chain in which production is triggered by the reception of a customer's order, which in turn is derived from actual demand (Koh et al., 2005). Orders are generally of low volume per specification and this system is often found in the aerospace or naval industry. The competitive advantage relies on short lead-times and actual completion of tasks in due time.
- Make-to-stock (MTS) is the opposite of the above with a push-type supply chain (Koh et al., 2005). Production is triggered by forecasting and companies rely heavily on that analysis to prevent loss of opportunity from an empty stock while keeping the inventory lean to prevent excess of stock and end of life losses. This manufacturing environment is usually used for mass produced products like consumer goods and its strength relies heavily on the accuracy of demand forecasts due to the fluctuations of the market.

  According to Imaoka (2012), MTO can be compared to an elevator that goes up and down by the push of a button while MTS may be compared to a train on a schedule based on past data.
- Mixed mode (MM) has been gaining momentum in the last few years because of the market constraints with short life cycles and variability of the products, leading to a large array of variations that need to be delivered to consumers in shorter and shorter lead-times (Bukchin et al., 2002), thus the need of combining the strengths of the MTO and MTS types with buffering and dampening techniques.

2.4 The product-market-supply-chain linkage

Companies and most commonly start-ups lack both time and resources to design each strategy separately. Fine (1999) proposed an operations management framework, proving that the parallel design of process, product and supply chain resulted in a company's increased operational capability. Afterwards, Markham et al. (2004) proposed the technology-product-market framework to explain how companies achieve success by combining their technology capability with the capacity to answer customers need while designing their products. It has become a crucial tool to overcome the Valley of Death, a

very well-known reason why business ventures fail, which lead them to insufficient market knowledge, management capabilities and a fragile internal structure (Lévesque et al., 2012). After this phase comes a time when start-ups start a 3R's (resources, routines and reputation) scaling-up process (Joglekar et al., 2013) that may lead them to a second Valley of Death when they are not able to embrace growth (Sutton el al, 2014).
Tedim et al. (2016) proposed a new Product-market-supply chain (PMSC) framework, based on Fine's and Markham's findings to overcome the growth problems of start-ups:

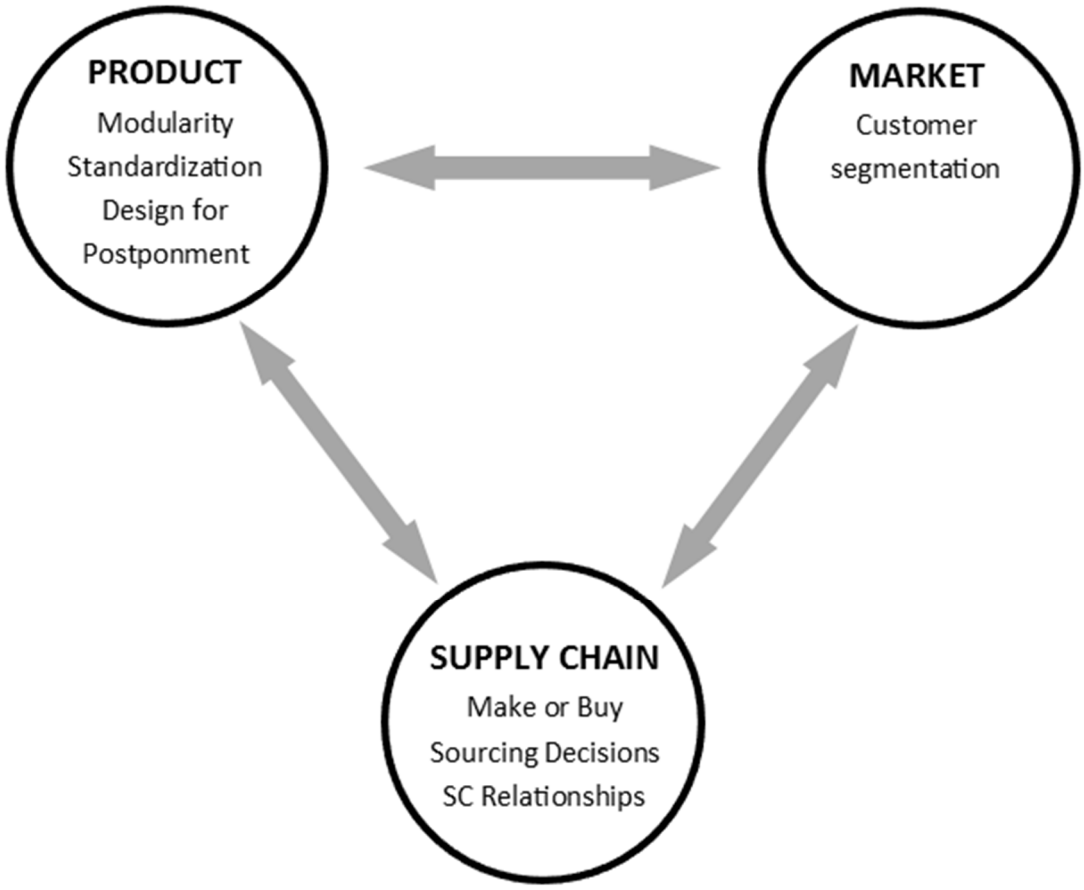

Figure 4 – Conceptual framework of the Product-market-supply chain (PMSC) linkage
Source: adapted from Tedim et al. (2016) - Supply Chain Strategy of start-ups Commercializing Emergent Technologies

Start-up growth is smoother if they are able to lower costs and lead-times at the same time they keep a dynamic balance between resilience and responsiveness (Khan et al., 2012). Based on that assumption, Tedim et al. (2016) sustain that, by thinking the design of the

product as they build their supply chain on a non-hermetic approach, start-ups should take into consideration three important factors when they design their supply chain:

- Modularity, which will help keeping costs down by reducing the supply chain's complexity which in turn will shorten time-to-market (Droge et al., 2012). This is particularly important for companies who integrate various components (and therefore, suppliers) in their products.
- Standardization, by using standard off-the-shelf components, companies can reduce lead-times by simplifying their products' complexity while being less prone to stock disruptions due to non-standardized components (Ulrich et al., 2000). At the same time, their scalability will become significantly easier.
- Design for Postponement, obviously the "one size fits all" is neither possible nor desirable in disruptive companies, therefore some kind of customization is required, even if the core of the product stays the same. By enabling later customization in their products, companies have the flexibility of answering their customers' need while keeping costs down (Fixon, 2005).

Today's markets complexity goes well beyond the purpose of serving a need. In fact, a product must comply with legal and regulatory requirements as well as certification standards while it retains attributes required by the customer such as convenience, short delivery time and, most of all, affordability.

By designing the suppliers network, companies must find the best combination of a "supply chain friendly product" with their needs of reliability, scalability and flexibility by means of three important decisions:

- Make or buy, companies must weigh their options on whether to build inhouse or outsource components for their products (Fine, 2006).
- Sourcing decisions, as mentioned in 2.4.4, companies must choose to integrate a single supplier or multiple suppliers, by procuring locally or globally.
- Supply chain relationships, as discussed in 2.4.5.

3. Methodology

Every research needs to have a well-defined approach with scientific criteria to produce credible results. Such process needs to have a well-defined method, from the beginning to the end of the research. Sousa et al. (2011) suggest that method definition should start by considering which are the questions one needs to answer, what the expectations are by the end of the process and what is the general objective of the study. After formulating the questions, one must define which is the most adequate strategy to gather scientific data in order to sustain the objectives one aims to reach (Sousa et al., 2011). On the other hand, it is also necessary to communicate the results of the research in an orderly and systematic way, to promote the dissemination of information – one of the greatest achievements of our time.

3.1 Formulating the questions

Rather than a topic heading, it is important to formulate a research question which, while being one of the most difficult phases of the research as there is not an exact script to follow (Tuckman, 2000), will also be crucial to understand what will be the right approach to the problem, to help structure the layout of the instruments to collect data and ultimately to allow for a successful analysis as an outcome. Good research questions are commonly the result of refinement through exploration of the theme rather than seldom found and should be raised under the following principles:

- Interesting
- Relevant
- Clear and simple
- Manageable
- Substantial and original
- Fit for assessment

For the current study, the proposed question is as follows:

- What is the linkage between business model and supply chain in healthcare start-up companies?

3.2 Research design

After defining the problem or field of study and reviewing the relevant literature, it is important to define a set of objectives to be met at the end of the research (Sousa & Baptista, 2011). Defining the methodology plan implies the selection of a strategy that will select which tools and techniques to use, undoubtfully conditioned by the proposed (Sousa & Baptista, 2011). The process begins when a target problem is identified and ends when the associated solution is clarified (Almeida & Freire, 1997)

This dissertation used a qualitative research method of investigation for an exploratory research of business model and supply chain dimensions in start-up companies in the healthcare sector with the objective of establishing a linkage between the two fields of study. Zikmund et al. (2012) condensed the properties of this type of analysis:

Exploratory Research	
Amount of uncertainty characterizing decision situation	Highly ambiguous
Key research statement	Research question
When conducted?	Early stage of decision making
Usual research approach	Unstructured
Examples	"What kinds of new products are fast-food consumers interested in?"

Table 4 – Comparison between exploratory and descriptive research methods
Source: adapted from Zikmund et al. (2012) - Business research methods

Exploratory and qualitative methods have the great advantage of allowing to study in great detail complex problems (Yin, 2009).

At some extent, an exploratory approach may infer misguiding information while trying to achieve qualitative and objective information because some bias may be induced due to interpretation, yet it presents some degree of flexibility and an adaptable character in exploring change which in turn may open future fields of study by identifying, at a very early stage, the adequate research type (Saunders, 2011).

Yin (2009) claims that trying to study change over time, while bridging different constructs, leads us to use a research method based on case studies. It is obvious that an experimental research is not possible because the subjects are independent entities and also, according to the same author, it is neither desirable to interfere in the development of the action nor to force milestones upon the studied subjects. Yin (2009) also argues that one of the key aspects on a case study approach is to apprehend the value that multiple sources of evidence such as interviews, documents, etc. will enrich the final results based on empirical evidence (Eisenhardt et al., 2007).

By using multiple case studies instead of a single one, although more time spending, the solidity of the analysis is certainly increased (Yin, 2009) and at the same time one can be certain to obtain a more solid analysis which will produce a wider and robust base for effectively build an accurate result by reducing interferences while correlating relationships to explain several phenomena (Eisenhardt, 1989), using change in business models and supply chains as a unit of analysis.

3.3 Research setting

The study focused on analyzing business models and supply chains by selecting start-up companies of the University of Porto (UP) as research setting because they are a rich source of information on their change patterns (Gersick, 2004) while maintaining its inherent uncertainty character as other start-ups.

Although university spin-offs are less market oriented and thus less experienced in management than corporate spin-offs (Clarysse et al., 2011), the fact that the companies selected for the study have all originated in the same higher education institution (UP) and develop their activity in the healthcare sector adds robustness to the study as all are subjected to the same ecosystem and the same constraints, such as sharing a common IP policy, using the same procedures to be brought to life according to a similar framework to design their business models (Osterwalder et al., 2010) and have access to the same financial instruments provided either by the UP, the government and venture capitalists for their funding.

Finally, a very important concern was the sampling of case studies. According to Yin (2009), "the typical criteria regarding sample size (…) are irrelevant" as long as "literal replication" is assured. In fact, having two dimensions to explore business models and opearations of start-up companies in healthcare, a sample of five companies was considered to be sufficient.

3.4 Data collection

The following table summarizes the data collection process used in this study:

Steps	***Description***
Initial investigation	Internet search of UP incubated start-ups and collection of contacts
Initial contact	Email to prospective case study companies. Conference call with interviewee to arrange the meeting
Generic data	Exploration of media and companies' websites in order to gather as much information as possible on their activities: type of product or service provided, funding, technology, etc.
Interviews	Total of five interviews made at the companies' location.

Table 5 – Summary of the data collection process

Based on the previous literature review, a structured interview guide with twelve questions equally divided between the thematics of business models (strongly influenced by Osterwalder et al. (2010)) and supply chain (using a similar approach with Barros et al. (2012) but this time for healthcare start-ups), with an introductory part to gather specific information from the interviewed companies. Its use was of relevant importance as to reduce interviewer bias and to underline which dimensions were more relevant for each question. Also, it is important to refer that, due to privacy or business secrecy and legal questions on some of the companies, it was decided that Osterwalder et al. (2010) Business Model Canvas topics on Cost Structure and Revenue Streams were not to be included in this study.

The five interviews took place during the months of May and June 2017 at the companies' location, after arranging a meeting with interviewees representing the start-ups. Their duration was around 1,5 hours and every interviewee authorized interview recording, in order to transcribe verbatim and complete the interviewer's annotations.

3.5 Data analysis

A screening process was set in place as means to synthetize collected data in order to transform the results of the interview in more manageable data. This process was possible due to the aforementioned recording of the interviews and cross checking with the interviewer's annotations. The treated data was organized in a table as presented in Appendix B, after which a software analysis using QDA Data Miner Lite was performed.

The results of the present research will after be analyzed and its assertions will be presented in a common Master's dissertation structuring model (Azevedo, 2011).

4. Results

In this chapter, the results of the interviews are presented and explored to identify relations and possibly to discover a longitudinal linkage between business model's evolution and supply chain evolution in the healthcare startups in analysis.

As previously referred, a total of five structured interviews with an approximate duration of 1,5 hours each were performed. The questions used during the interviews can be found in Appendix A and the summary of those interviews, which was obtained from transcriptions from the recorded interviews combined with notes from the interviewer, can be found in Appendix B.

The procedure used in this analysis comprises an historic overview of the companies, followed by an exploration of the different dimensions and key words that were considered while designing the structured interview on business models and supply chains. Finally, in order to evaluate similarities and/or differences and their causalities, a comparative study was performed in order to produce a set of conclusions.

Below is a list specifying, for each case study, the healthcare industry sub-sector where the startup fits, and the position of the interviewee within the company:

Case Study	***Healthcare segment***	***Interviewee Position***
A	Medical training software	CEO
B	Healthstyle (wearables)	CEO
C	Medical registry software	CEO
D	Cyber-security, authentication and integration Software	Operations Manager
E	Biochemical Analysis	Founding partner

Table 6 – List of start-ups in the healthcare sector interviewed for the study

4.1 General overview

Before the contextualization and historic overview of the five case studies, it is important to make two critical considerations of important aspects about the following case studies. First, some of the details such as actual business models, revenue streams, funding or product details might have been deliberately kept in secrecy by the companies because they represent confidential information. Yet, that omission does not affect the accuracy of the study as there is enough and relevant data to build the analysis. Also, it was neither the intention of this dissertation to perform a deep exploration of business models but rather to find relevant connections between the design of business models and supply chain models to come up with relevant information about their linkage. The interviews evidenced that all the companies shared the use of the BMC as a resource for management and internal organization but also in the funding process as it was commonly referred as being the unofficial tool used for business model presentation for funding purposes in UP.

4.1.1 Case study A

This startup develops and commercializes a training software for medicine students that targets a loophole found in medical education regarding the inability of every one in five future practitioners in performing a certain type of cardiorespiratory examination correctly and returning a legitimate diagnosis.

The product was created after the idea that allowed an UP student to get his doctoral degree. In 2011, that idea was financed and developed to become a product together with another PHD student under the supervision of two UP professors (one of them was the interviewee, serving as the company's CEO, with a ten-year experience in digital sound processing) after identifying in the market the need for such a solution. The company was incorporated later in 2013 and began trading in 2014. The decision that led to its creation was a major order from an international client and the difficulty of a non-lucrative organism like an university to trade and profit from a product. The company was

exclusively funded with the founder's equity, after a successful licensing of Intellectual Property from University of Porto, resulting in the payment of royalties.

The product evolved from an application available at Apple's and Google's app stores designed for mobile devices (tablets and smartphones) specifically aimed at medical students to a product+service package sold to medical schools, after a partnership with several professional associations of medical specialists in cardiology and pneumology which served the purposed of enhancing the company's visibility and then turned this unique package in the only skill certification tool sponsored by those associations. Such advantage was only possible because the company was a first mover.

The package is built by the collection of live sound samples from patients in each medical school. A database is then built by cross-referencing the sound samples with symptomatology, medical reports, diagnosis, therapeutics and results. The company aims at delivering a unique and continuously improved package by providing maintenance to the system, installing software upgrades to increase usability and widen databases per sampling and illness sampling or by the client customization requests.

Over time, the team has grown from four people to six people by adding marketing & sales and management personnel.

4.1.2 Case study B

Following an UP's student in Innovation will to create his own business venture, this company was born in 2007 from the initial idea of licensing research produced by INESC TEC (Institute for Systems and Computer Engineering, Technology and Science) in the area of sensors technology applied for the human body and transforming it into a disruptive business idea.

The initial idea behind the product was to design a tool to evaluate the evolution of health problems and the effectiveness of therapeutics in a population suffering from lower limb conditions such as amputees using prosthetics, diabetics and patients suffering from deviations, abnormalities, malformations and fracture recovery. The product was initially

comprised of a set of specific sensors and a data processing software in two levels of configuration for static application and one portable solution, with new applications down-the-road added by distributing sensors throughout the whole body for muscle-skeletal evaluation. Further segments where explored by creating variations used for sports medicine, tested by professional football teams, and for the running enthusiast.

INESC TEC and public funding instruments were the initial investors on this start-up. The company had a long time-to-market and suffered a number of setbacks, mainly in the form of regulatory, certification and funding obstacles for its Portuguese based custom production. This ultimately led to the decision of abandoning the medical healthcare market in 2010, followed by the sports medicine market in 2013. After a market survey, they were able to redirect their technology, focusing on the health style segment with a wearable solution. The later iteration of the product was developed using feedback from their IOS/Android application. The company grew from a one-person enterprise to sixteen people while working in the medical area. At the time, it gained an important savoir-faire in product design it topped at twenty eight workers.

After aborted partnerships with a major sports equipment brand and with IEEE (Institute of Electrical and Electronics Engineers) in a smart shoe project, the company's CEO (Chief Executive Officer) (the interviewee) decided to terminate the project later in 2016, with the company effectively closing its doors not long after the interview. As a side note, the end of this start-up occurred at a stage in time where the global supply chain was designed and tuned, with actual sales revenue incoming from one of the larger online sales platform in the world due to withdrawal of public funding.

4.1.3 Case study C

This company was born later in 2013 by two UP researchers in the area of medical registry software as the result of market demand, following the growing volume of business. This meant hiring new programmers and investment in marketing, which was proved to be impossible to perform as a service provided by a non-lucrative public institution. The company, after successfully licensing IP from UP, grew from the initial two workers plus

a partner manager to a total of seven workers spread out through software programming, management and marketing & sales using exclusively their own funding and operated its first sale in 2014.

Their product uses a different approach for a tool used for basic daily work in hospitals, clinics and clinical practices that is easier to operate relying in a form filling interface according to the clients' needs and provides active feedback capability by allowing data visualization, data management and cross-referencing that can be used in clinical trials and medical research.

This start-up's success was granted by a long experience in consulting to external customers, using key clients as opinion-leaders and spread the word in the medical area in conferences and clinical associations' meetings and by providing a superior level of service to the client by customizing a product to his own needs and requests. The on-site presence during development stage, the monthly follow-ups and updates every three months in a product with a two-year product-life also explains the success achieved with the development of the product being made entirely in Portugal.

4.1.4 Case study D

In 2013, a group of three UP researchers (including the interviewee who is the company's CEO) started providing cyber-security software for data traceability/monitoring, authentication and integration, along with consulting services for the public sector in hospitals and regional health authorities following a market need caused by a reform of earlier that year of the Data Protection Directive 95/46/EC and the subsequent General Data Protection Regulation GDPR EU 2016/679. Such regulation enforces data protection for all European Union (EU) individuals to be applied from 2018 onwards. Besides the public sector, they foresaw demand from private hospitals, clinics and clinical practices, as well as the pharma-industry, which led to the creation of the company in 2013.

One of the founders is a key resource as he has served as an advisor for the revision of the substituted directive as well as for the substitute directive. The collective knowledge from a combined experience of more than 30 years of the three founders, the very advanced scientific approach and a confidence based contact network gathered through years of financed projects transformed this start-up in a market leader, going from a four-people team when the founders hired a manager in 2013, to a fourteen-people enterprise who work in project management, administration, programming and R&D.

Another key aspect of this start-up is their software based on open-source code, which reduces time-to-market from four or five months, with one version per year and four annual revisions, also due to their proximity relationship with their customers.

4.1.5 Case study E

The last interview was performed with a founding partner of case study E, a biotech start-up. The interviewee has more than twenty years' experience divided between the clinical analysis area in one of Porto's biggest public hospitals which is connected to UP's Medicine Faculty, along as being a researcher and teacher.

Together with two other founders, she has studied in depth the problem of long waiting time for patients before a clinical analysis identifies the source of the illness in case of a bacterial infection and also the challenges related to antibiotic susceptibility and increased bacterial resistance. Nowadays, to evaluate which is the best therapeutic to a certain bacterial infection, the technique that is commonly used worldwide is using samples taken from the patient to incubate for forty height hours, after which an analysis is made to evaluate the causes of such infection. During that waiting time, patients are given wide spectrum antibiotics that do not necessarily target the bacteria that is causing the infection, which has the undesired side effect of increasing bacterial resistance. On the contrary, this start-up's approach consists of a new technique, built with off the shelf components together with a new methodology to obtain results in just under one hour. The reduction of the diagnostic time allows for a very rapid intervention on the patient's illness and, at

the same time, an improvement in misuse of antibiotic therapeutics. This product also as advantages over its competitors by means of a higher cost-effectiveness and lower running costs.

The three founders identified the market potential for this idea and decided to create their own company in 2013, raising a first round of funding from private venture capitalists. Further funding was raised in 2017 from public funding (Horizon 2020). Presently the company is already in the process of European certification. This regulatory process is mandatory and an usual internal EU procedure to guarantee medical safety use. Therefore, this company is developing six-month trials and looking for new market opportunities in the veterinary, pharmaceutical and food sectors, growing their staff to a total of ten people. One important caveat: although very knowledgeable about all technical aspects of the company, the interviewee seemed less comfortable to speak about the management aspects which were tackled by one of the other founding partners. This may have led to some misrepresentations and distortions found on the sampling.

4.2 Analysis of results

The summarized interviews were the subject of a study with QDA Data Miner Lite, a data management software for qualitative analysis. After coding the total of 13 dimensions (distributed by seven dimensions related with business model and six dimensions related with supply chain) and their associated keywords (59 nodes, 35 of which are related with business model keywords and 24 related with supply chain keywords), the software produced a set of treemaps that allowed for an analysis of the number of node references and the extent of node sources, respectively, assigning attributes by size and color. Treemaps provide a high-level view at the same time they provide an excellent tool for detail visualization. Although they offer an excellent tool for large data sets and multiple dimensions, they do incur in some distortions due to limited space on the graphic canvas that may result in poor handling of small and zero values.

The software also has the capability to export Excel files whose data helped to render another set of graphics that allowed for the building of a chain of evidence in which every single driver is identified per company and thus counterweight the distortion effect of the treemaps.

4.2.1 Business model results

The Customer segments treemap is sharply identified by all companies: A, C, D and E aim at Niche markets while B targets a Mass market:

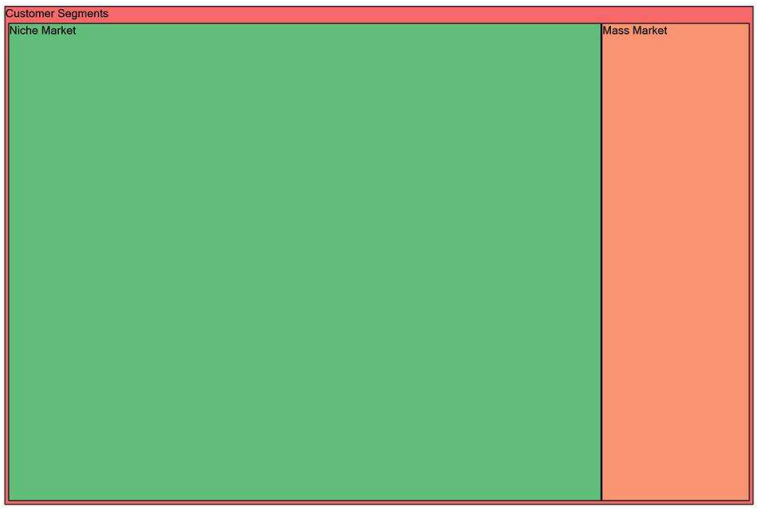

Figure 5 – Customer segments treemap

As evidenced by the graphic below, case studies A, C, D and E have their core activity in niche markets while case study B targets mass markets:

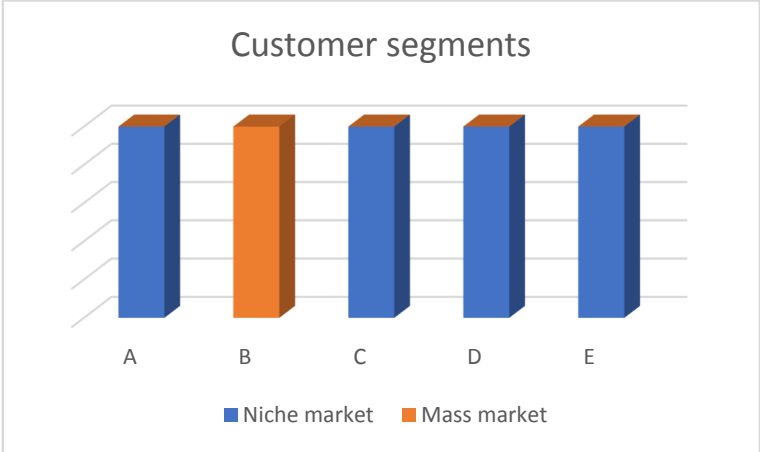

Figure 6 – Customer segments graphic

The Value proposition results appear rather disperse in its respective treemap, yet performance seems to be a key element for all companies. No specific pattern among companies was identified. This is attributed to the specifics of each business model and therefore, distinct for each company.

Figure 7 – Value proposition treemap

The distribution per company confirm that Performance is a key indicator for all companies:

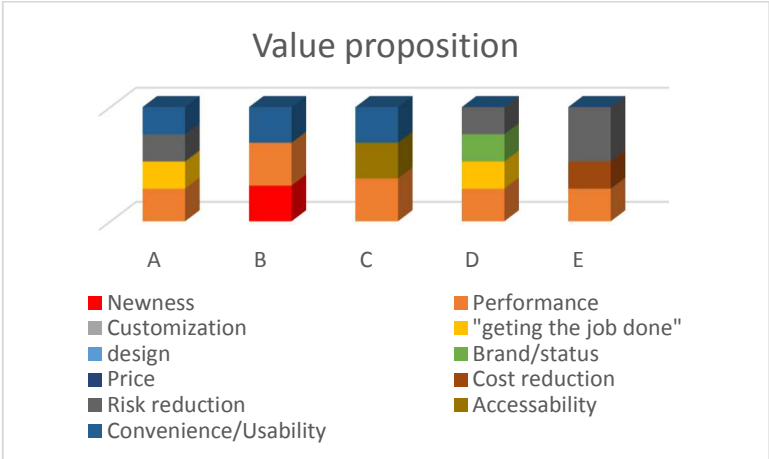

Figure 8 – Value proposition graphic

The importance of Own channels over Partner or Mixed channels is not evenly distributed among the studied start-ups:

Figure 9 – Channels treemap

There is a pattern among software companies, probably because of the way they do business: their customer portfolio derives from their contact network and therefore they use their Own channels. The wearables company has a similar pattern to the biotech: they both use their own channels or their partners channels to promote their products. Yet, a third strategy is used, a mixed approach. Although this could be interpreted as a combo of own and partner channels, it was ascertained that the companies (the start-ups and their partners) co-promote their products (usually in science fairs, technical exhibitions and medical congresses, where they share a stand with partners).

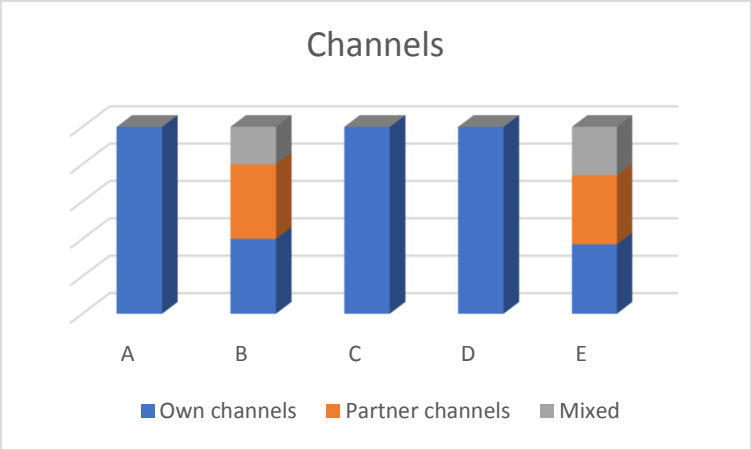

Figure 10 – Channels graphic

The Key resources dimension has a transversal result throughout the sample:

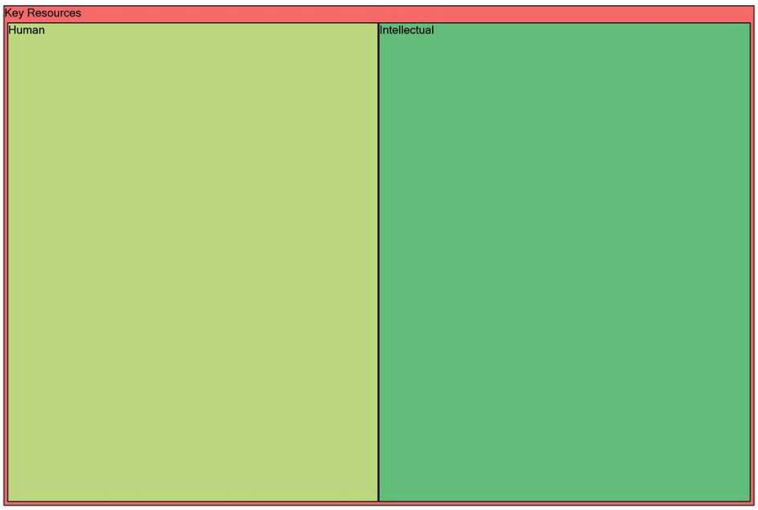

Figure 11 – Key resources treemap

The results are peremptory as human and intellectual resources are equally important for these companies. Neither financial nor physical resources were determinant for these companies. Financial resources may have been excluded because of the choice to not include financial aspects in this study, which might have led interviewees to not considerer it as a possible answer for this question. Physical resources may have been excluded because physical resources are assured by UPTEC's incubation. Therefore, the major richness of these start-ups is actually their Intellectual property (IP).

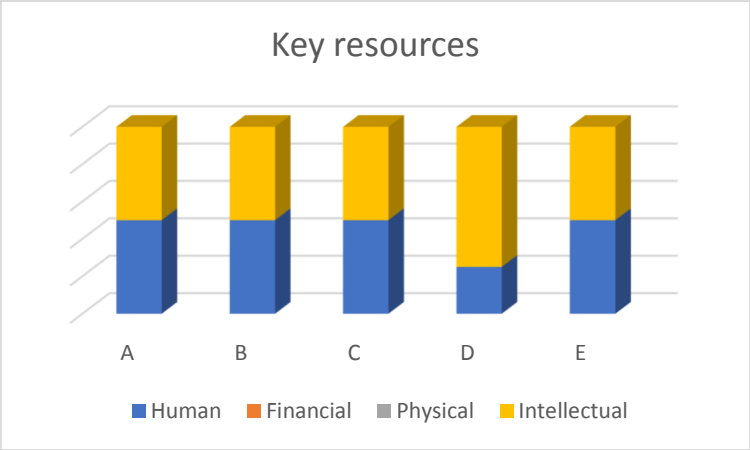

Figure 12 – Key resources graphic

Production and Platform/Network related keywords are more common for the Key activities dimension:

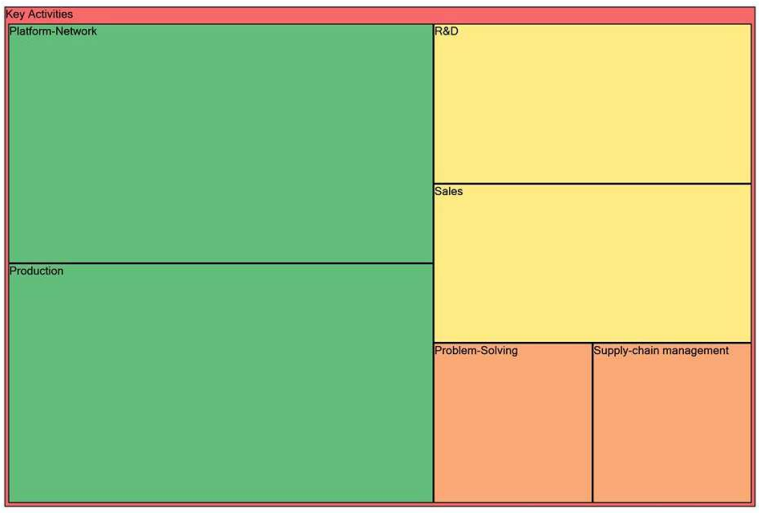

Figure 13 – Key activities treemap

Production and Platform/network have an evenly representation among start-ups A to D as Key activities. Every of these start-ups evidently put a considerable amount of effort and time developing their products and they all have a software platform to support their clients. The fact that company E refers exclusively R&D is considered to be an anomaly, which is further explored later.

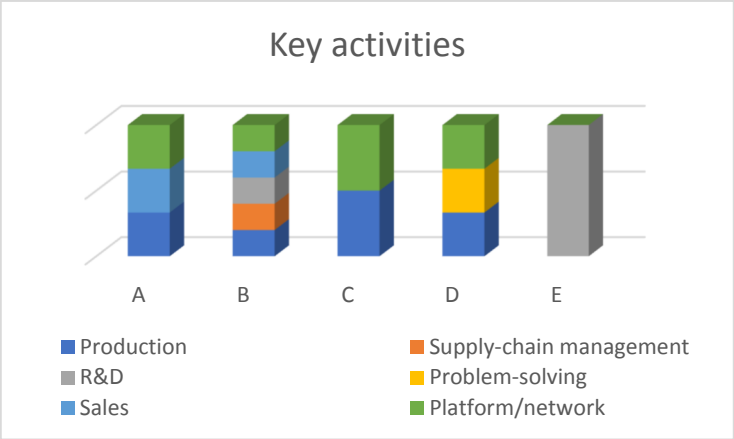

Figure 14 – Key activities graphic

The Buyer-supplier relationship assumes an important role when choosing Key partners:

Figure 15 – Key partners treemap

Regarding the Key partners, there is a common indicator these companies rely on their Buyer-supplier relationship for their success. Companies B and E share a pattern because of the importance of the Strategic partnership and Strategic alliance dimension due to the nature of their business: they must rely on multitude of suppliers to get the parts that form their products.

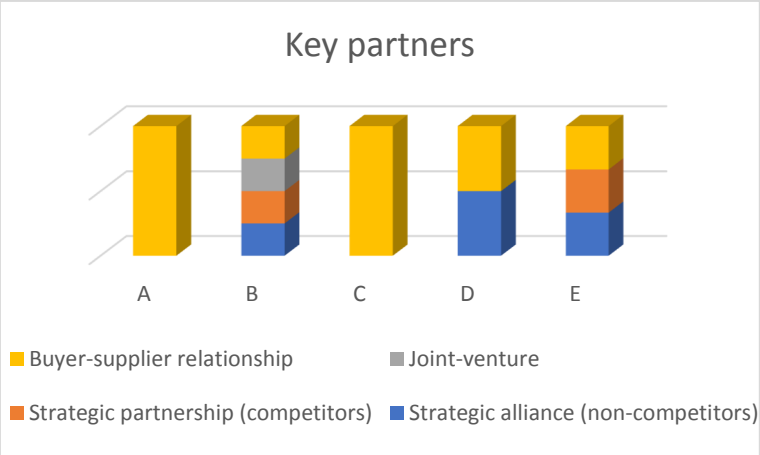

Figure 16 – Key partners graphic

Personal assistance is the main keyword for Customer relationship, followed by Co-creation and Self-service/Automated service:

Figure 17 – Customer relationship treemap

The Customer relationship dimension once again shows a pattern among software companies as they develop proximity relationships with their clients because the specificity of their products and customization needed requires so. The wearables and the biotech start-ups share a self-service relationship with their customers as their product, although customizable, is sold in standard packages with add-ons and therefore they establish a parted relation, which undoubtfully explains the channels by which they promote sales.

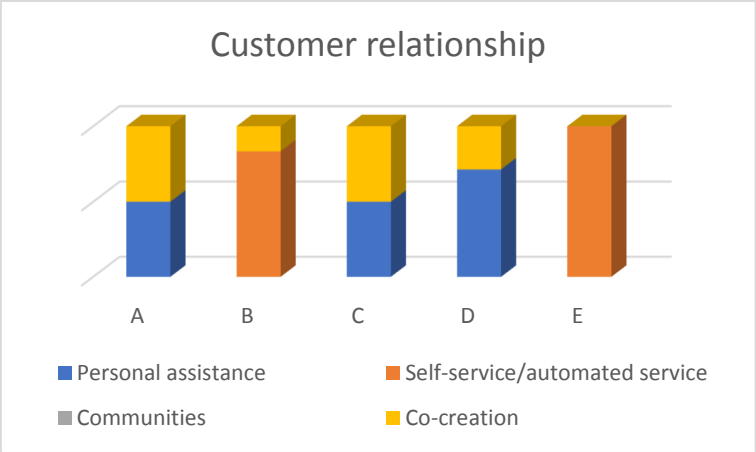

Figure 18 – Customer relationship graphic

4.2.2 Supply chain results

Concerning the Competitive differentiators, the start-ups focus most of their attention on the Service level and Design capability:

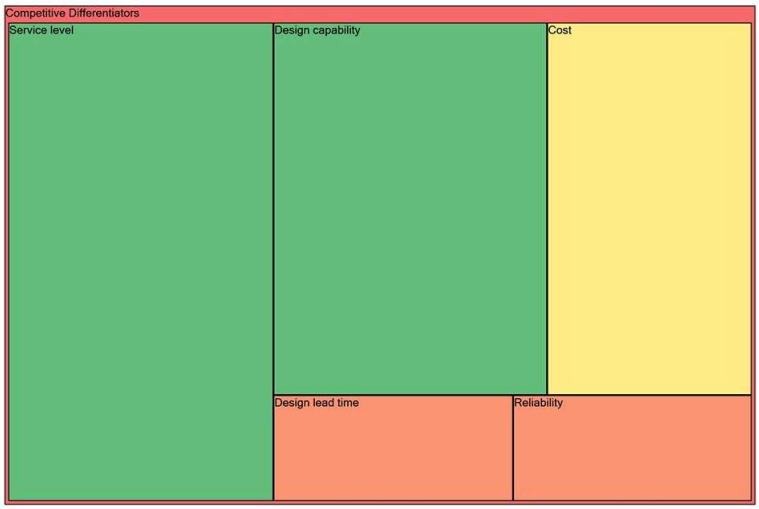

Figure 19 – Competitive differentiators treemap

The competitive differentiators dimension has a clear winner equally distributed among all companies: the service level, measuring the type of service to be provided, performance level, supply time-frames and issue resolution time-frames is obviously very

important for these companies and start-ups in general because they have to stand out from their competitors as they have to assert themselves in the market as newcomers. Although not equally distributed, the Design capability and the Cost dimensions also occur for the same reasons aforementioned.

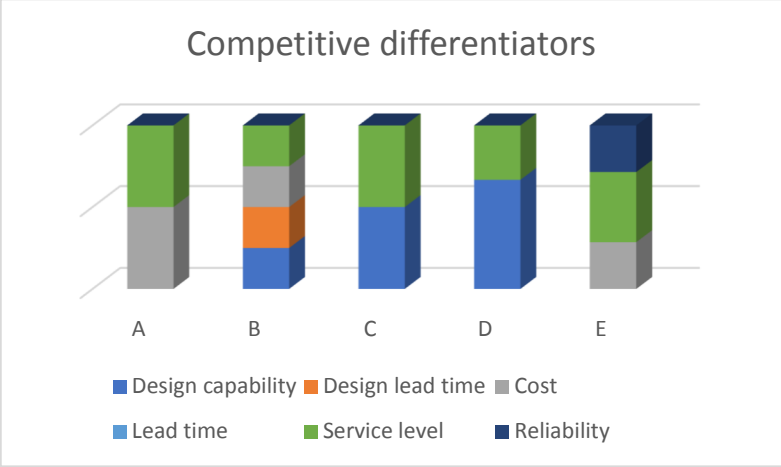

Figure 20 – Competitive differentiators graphic

Globally, the Time window for delivery is the most important keyword analyzed related with the Demand characteristics dimension, followed by Product life cycle:

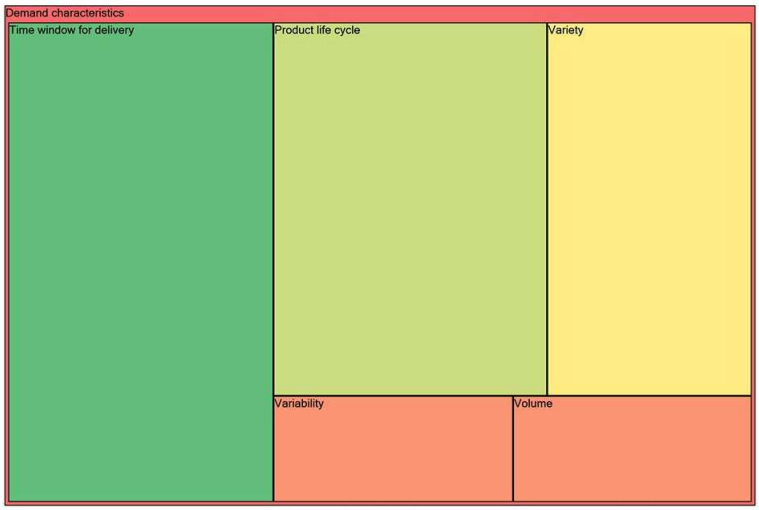

Figure 21 – Demand characteristics treemap

The Time window for delivery stands apart as a Demand characteristics dimension because it is present in all the companies and its importance may be related to the need to provide a high service level by controlling and shorten their lead-times.

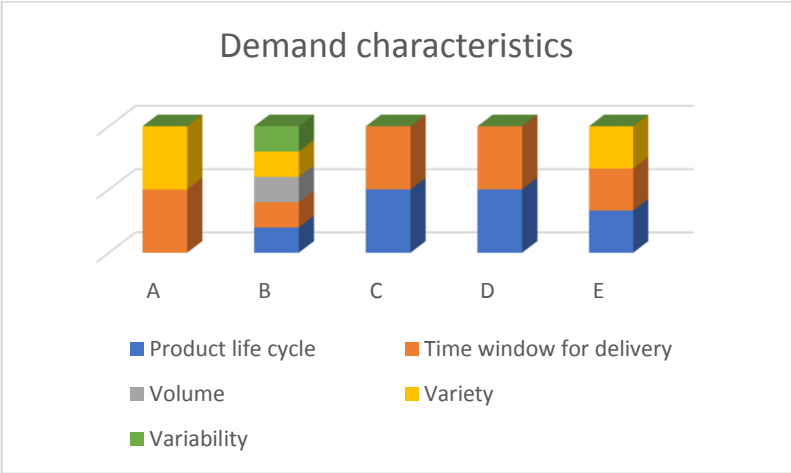

Figure 22 – Demand characteristics graphic

Replenishment lead times is the most focused keyword on Supply characteristics, followed by Reliability of suppliers:

Figure 23 – Supply characteristics treemap

The most relevant fact of the Supply characteristics dimension is the overwhelming weight that Replenishment lead-times represent, probably to keep a high Service level

and to cement their position in the market as newcomers. Another pattern can be observed for companies B and E because, as previously referred, their products rely on several components from an equal number of suppliers who need to have an availability of parts and a reliable supply chain.

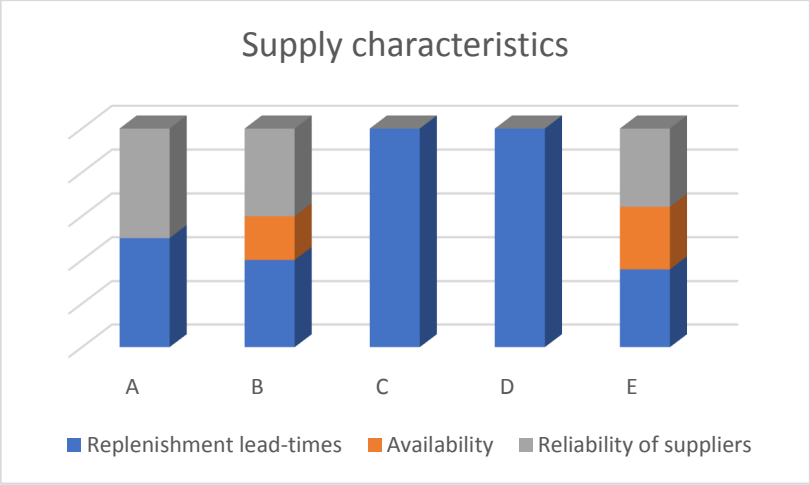

Figure 24 – Supply characteristics graphic

For these companies' Sourcing strategy, Local vs. global is the most important keyword, followed by Single vs. multiple suppliers:

Figure 25 – Sourcing strategy treemap

The Sourcing strategy dimension shows the shared importance of the definition of the supply chain with an equal distribution of Single vs multiple and Local vs global keywords for these start-ups. Yet, although not explicit, another pattern can be observed: software companies choose a single local supplier as they generally collect or work on their clients' database and the wearables and biotech selected a multiple set of suppliers globally.

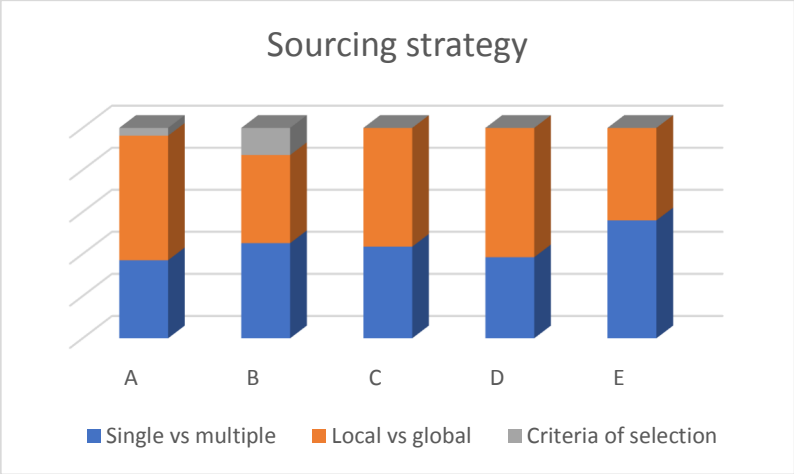

Figure 26 – Sourcing strategy graphic

The Supply chain integration assumes the larger number of references, followed by Strategic partnerships in the Supply chain relationship dimension:

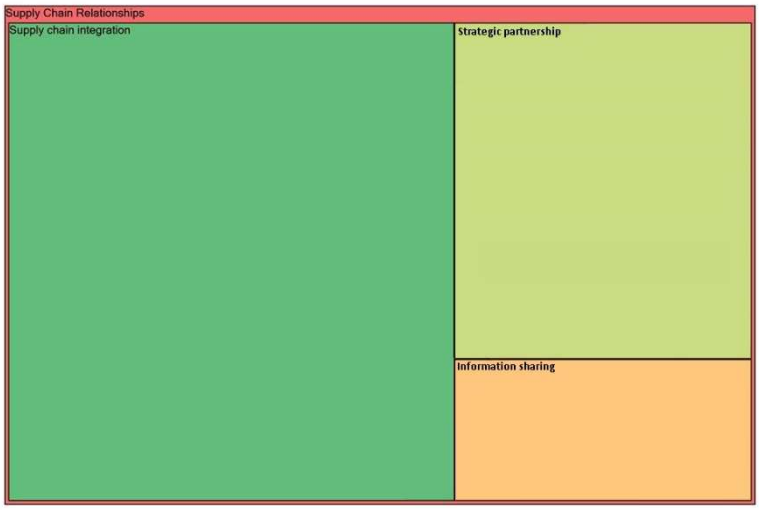

Figure 27 – Supply chain relationship treemap

The Supply chain relationship shows another pattern among software companies as they consider Supply chain integration to be an important aspect of their supply chain because, as mentioned above, their raw material is the clients' database and they chose to do their own sampling. Companies B and E chose to establish Strategic partnerships because they need to join forces with a multitude of suppliers together to assemble their product.

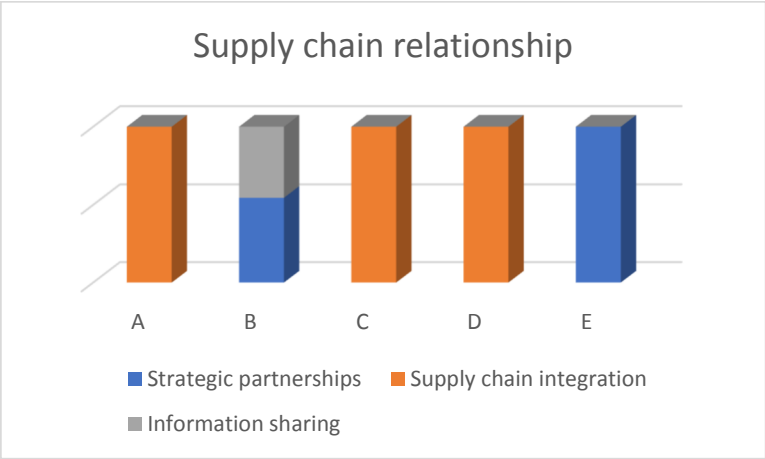

Figure 28 – Supply chain relationship graphic

Make-to-order has an evident prevalence over Mixed type in the Production environment dimension:

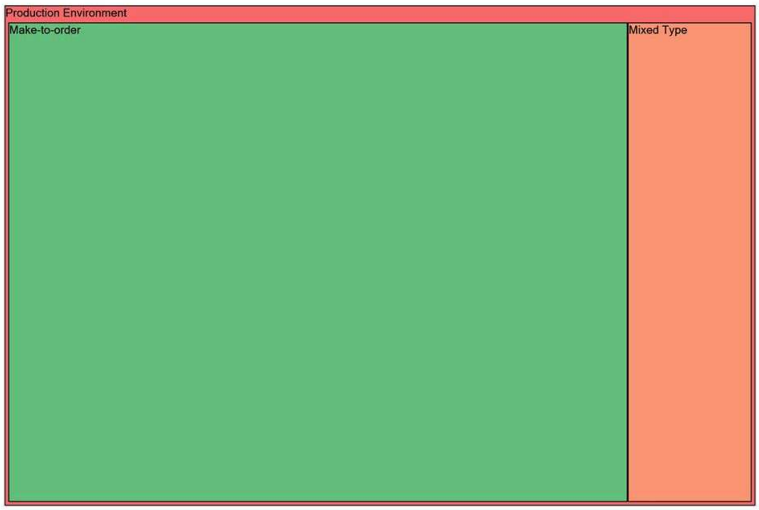

Figure 29 – Production environment treemap

The Production environment dimension shows both the software and the biotech companies chose a Make-to-order production type because of the low volume, high value Niche market they aim at. Company B has to choose a Make-to-stock production type because of the high volume, low price mass market they are focused in.

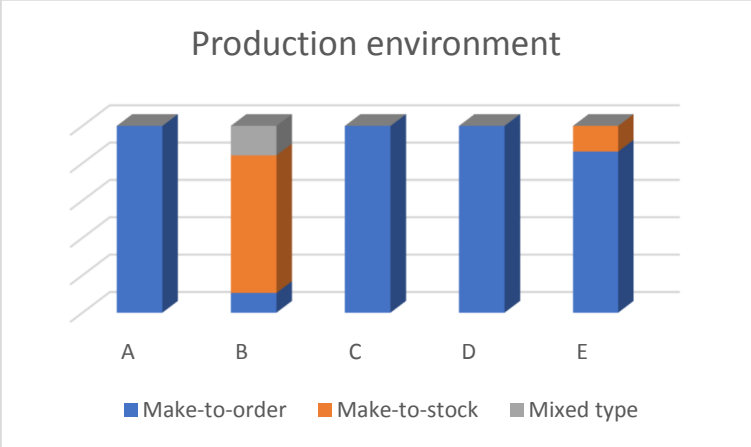

Figure 30 – Production environment graphic

After all individual results per dimension were established, a global analysis of all the nodes was ascertained with the results shown on the following treemap:

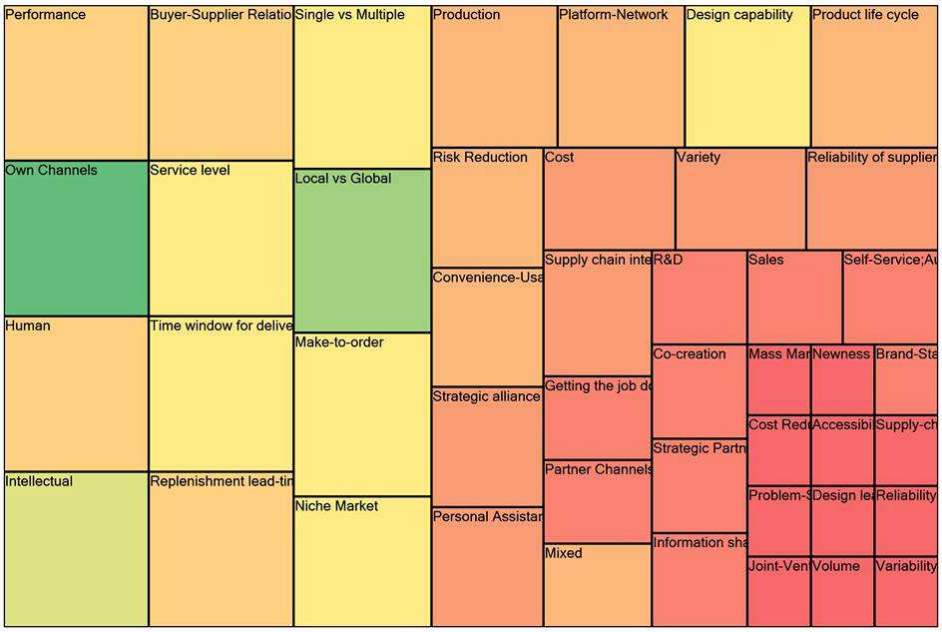

Figure 31 – Global treemap

The most relevant keywords are summarized in the following table:

Dimension	*Keyword*	*Field of study*
Channels	Own channels	Business model
Sourcing strategy	Local vs global	Supply chain
Key resources	Intellectual	Business model
Value proposition	Performance	Business model
Key resources	Human	Business model
Key partners	Buyer supplier relationship	Business model
Supply characteristics	Replenishment lead-time	Supply chain

Table 7 – Most relevant keywords per dimension globally

4.3 Discussion of results

By cross-referencing the most relevant keywords of the business model dimensions with the supply chain dimensions that were, simultaneously, highly referenced in the interviews and were evenly spread between every company, some pertinent relations emerged after a node analysis:

	Value proposition	*Key resources*	*Key activities*	*Key partners*	*Customer relationship*
Business model	Performance	Human/Intellectual	Production	Buyer-supplier relationship	Co-creation
	Competitive differentiators	***Demand characteristics***	***Supply chain characteristics***	***Sourcing strategy***	**-**
Supply chain	Service level	Time window for delivery	Replenishment lead times	Local vs global	-

Table 8 – Most relevant keywords per field of study and per dimension

The most important keyword for the Value proposition is Performance, which has been studied by Van Gelderen et al. (2000) as being dynamically influenced by strategy in small start-ups and, therefore, impacting on every characteristic of the company, including supply chain. The Time window for delivery (Demand characteristics dimension) is an important factor for competitiveness in the market of innovative goods (Christopher et al., 2000). Replenishment lead times (Supply characteristics dimension) may be widened in a global economy with the increase number of suppliers, adding pressure to the supply chain network (Christopher et al., 2006). Due to the innovative characteristics of the products these start-ups commercialize, the variability of lead-times because of quality issues, limited and unreliable suppliers and potential process changes constraints obviously affects performance (Lee, 2002). Both aforementioned aspects are very important for the companies' performance because their management is crucial if they want to keep an optimal Service level (Competitive differentiators dimension) as a competitive advantage allowing for a bigger differentiation in the market. The choice between a Local vs global network of suppliers (Sourcing strategy dimension) is another important factor, as Baum et al. (2000) established that Performance is directly influenced by the choice of strategic networks because of the balance between costs, quality and lead-times with stability and predictability (PrasannaVenkatesan et al., 2002; Albino et al. 2002).

The Key resources dimension data revealed that Human and Intellectual factors are predominant and equally distributed among the start-ups included in this study. In fact, these companies have referred that their know-how and experience designing disruptive technology, as well as their capacity to reach their markets via their contact network and establishing a good relationship with their customers (companies A, C and D), with their suppliers (company B) or both (company E) is of the utmost importance for the sustainability of their businesses. These relationships promote a high Service Level by making the customer a part of the product design process (companies A, C and D) or by managing the multiple suppliers (company B and E) in order to accomplish the stipulated Time window for delivery and Replenishment lead times. The Sourcing strategy assumes again the importance of balancing costs, quality and lead-times with stability and predictability of the suppliers (PrasannaVenkatesan et al., 2002; Albino et al. 2002). By the above remarks, it is logical that the Buyer-supplier relationship (Key partners

dimension) assumes such a high relevance whilst cross-referenced against the supply chain dimensions.

The Key activity most equally shared by all companies is Production. The relation between production and supply chain is both logical and of the utmost importance. All companies need to accurately predict their Time window for delivery and the Replenishment lead time by sorting their suppliers at either a Local vs global level in order to achieve a good Service level. The exception is start-up E that has its core activity in R&D, yet this is thought to be a distortion related to the fact the interviewee, although being a founder. Might not be so involved with the company's management and probably by speaking about her own role in the company instead of the company itself.

All companies share some degree of Co-creation in their type of Customer relationship. Software companies A, C and D design their products with the help of their customers and the product company B sells was developed using feedback from their application. This creates a high Service level by answering, directly or indirectly, to the customer's needs. This partnership also allows for a bigger predictability and accuracy of the Time window for delivery and Replenishment lead time by aiming at specific suppliers and shortening their total number, releasing pressure over the supply chain network (Christopher et al., 2006). This increase in stability and predictability automatically cuts down costs and lead-times (Time window for delivery and Replenishment lead time) and increases quality (PrasannaVenkatesan et al., 2002; Albino et al. 2002).

Again, the exception is company E. Yet, although not explicitly referred in the specific answer to this question, the level of partnership between this biotech start-up and its partner companies such as specific customized equipment manufacturers may suggest the importance of feedback from the customers and consequently of co-creation. Unfortunately, it was not possible to ascertain to a higher level of accuracy such discrepancies at the time this dissertation was elaborated due to unavailability of the interviewee.

It is possible to establish a relation between the PMSC linkage (Tedim et al., 2006) and both the BMC and supply chain dimensions by exploring the contents of the general overview in section 4.1 and the keywords ascertained in section 4.2. The Product

component is based on Modularity, Standardization and Design for postponement. Every start-up as referred these dimensions in each of their overviews:

- Start-up A offers a software with different cardiology and pneumology modules that are installed according to the customer's needs of customization. One of the main obstacles the company was challenged with was the need to come up with a standard to data sampling which led to establishing partnerships with several professional associations of medical specialists in cardiology and pneumology, ultimately resulting in a sponsorship of this software as a skill certification tool. The add-on modules were built in such a way that the collection of samples from the clients' patients was one of the last phases before delivery.
- The product sold by start-up B is offered as a combination between six sizes of inner soles and three colors of a wearable device, thus making it easier for the company to standardize the items by combining a finite number of modules. This combination is made at their retail partners' warehouse just prior to shipping.
- The software sold by start-up C has a basic standard from which it is customized according to the customers' requirements by means of specific modules. The final version of the software implies for it to be tuned after the system is implemented at the customer's location.
- Start-up D's software is built using standard open-source code which is suited to the customer's requests by means of additional modules. The distinct specifications of the product, involving the customers' data base, involve adaptation and problem solving at the customers location.
- The technology that start-up E built uses off the shelf components that make it easy to standardize the product. It can also be customized according to the clients' needs by using different add-ons for distinct kinds of bacterial infections, even allowing for modification of the product later on.

Under the Market component we find the dimension Customer segmentation, which is similar to BMC's Customer segments. Every company has clearly identified their market, with obvious differences because of the type of product but nevertheless they identified their target market in a very straightforward way: companies A, C, D and E operate in

Niche markets and company B operates in a Mass market, as can be seen on figures 5 and 6.

The Supply chain component has three dimensions: Make or buy, Sourcing decisions and Supply chain relationships. The Sourcing decisions dimension is related with SC's Sourcing strategy: by observation of figures 25 and 26, we can retain the fact that this is another set of keywords that was not only common to all companies but presented a similar behavior among them. The Single vs multiple and Local vs global keywords were also discussed on the start-ups' overview, together with the Make or buy option: by discussing how they put their products together, companies outlined the decision of which parts were to be produced or assembled inhouse and which parts were to be sourced and where would they be sourced from, also discussing some difficulties they have encountered until they could reliably supply their products to their customers. The Supply chain relationship is similar to the BM's Key partners dimension and its Buyer-supplier relationship has overwhelmingly showed its importance to these companies.

By observing the global treemap, it is established that five out of a total of seven of the most relevant keywords are related to business model, as opposed to only two that are related to supply chain. In fact, by observing figure 31, answers to the business model part of the questionnaire were more structured and accurate, providing for more elaborate references from the interviewees. By having previously used the BMC as a tool to design their own business models because of the widespread use of this concept throughout UP, they were very familiar with the dimensions. This resulted in more references related with the business model. On the opposite side, it was found that answers to the supply chain part of the questionnaire were less accurate and the interviewees showed unfamiliarity with some of the supply chain's dimensions, with the need for the interviewer to clarify those dimensions and keywords. This resulted in a less structured, yet direct set of answers (sometimes pointing to a specific keyword) which produced a compact amount of data, and consequently contributed with a smaller weight to the global treemap. It is considered that the companies have not neglected the supply chain, yet the use of a formal approach such as the BMC to make a structured design would have increased the familiarity and therefore, the visibility of the dimensions at stake. For instances, start-ups A, C and D had built a rudimentary supply chain along the years, without a formal

approach, prior to their creation as service providers. This was made by integrating their suppliers (Supply chain integration) as needed and the lack of the formal approach was balanced by the slow business rhythm. Start-up E built a Strategic partnership along the years with their suppliers, who are also Key partners. This explains why they rely not only in their Own channels but also in their Partner channels or a Mixed strategy to approach their clients. In fact, the most considerable effort to build a supply chain was made by start-up B. They have walked the extra mile by cultivating stronger Strategic alliances resulting in Joint-ventures, which explain the reason why they are the only company where Information sharing with their partners became crucial.

The relations found in the cross-referencing analysis, the confirmation of the PMSC linkage and the unformal approach to the supply chain design led us to assume that a tool which could use the dimensions studied by Barros et al. (2012) would be very useful in identifying the key aspects of each start-ups' supply chain. Such tool, using a familiar visual approach similar to the one used by the Business model canvas could be named the Supply Chain Canvas (SCC):

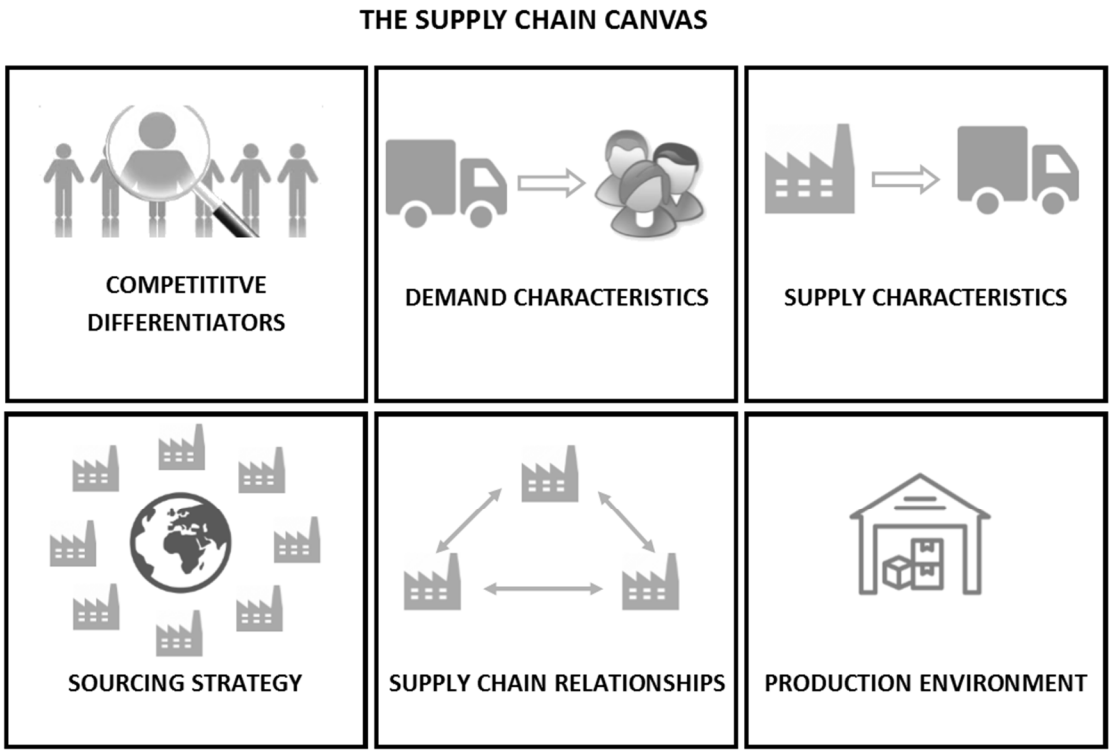

Figure 32 – Supply Chain Canvas

This new canvas could be articulated with the Business Model Canvas to embrace a wider range of variables that management needs to assess in order to drive its business through a sustainable path. Joyce et al. (2015) have introduced the concept of a triple layered Business Model Canvas, specifically referring the benefits of having one unique tool allowing for change management, whilst dynamically balancing the interactions between the business model and such important and defying aspects as environmental and social responsibility by introducing, respectively, the Environmental Life Cycle Canvas and the Social Stakeholder Canvas. This multi-level approach expands the range of the original Business Model Canvas, which was never exempt of criticism: Rosenberg et al. (2011) implied that such a summarized approach using a canvas with nine divisions didn't account for many important organizational management characteristics such as competition analysis, business objectives, performance measurements, strategy management and corporate structure. By using the Business Model Canvas and the Supply Chain Canvas (SCC) in unison, management could therefore be better prepared with a unique set of tools to face demanding clients, volatile market contexts and a global network of suppliers by dynamically adjusting their companies at a faster pace.

5. Conclusions, limitations and future research

5.1 Conclusions

The objective of this research was to explore business models and supply chains of start-ups in the healthcare, expecting to find a linkage between both fields of study. During the present research, after analyzing the data collected data from the interviews, it was observed that there is in fact a linkage between business model and supply chain conceptualizations. Such data was processed to evaluate similar patterns between start-ups and the studied dimensions were cross-referenced using a qualitative analysis software. This allowed to extract the set of keywords that were, simultaneously, given a higher relevance via software coding and evenly spread between every sample company.

A linkage between the PMSC framework and the BMC and supply chain dimensions was also found given that they share the same core ideas:

- PMSC's Product components were referred in the general overview of the start-ups.
- PMSC's Customer segmentation is similar to BMC's Customer segments.
- PMSC's Make or buy and Sourcing decisions are related to SC's Sourcing strategy.
- PMSC's Supply chain relationships is related to BMC's Key partners.

As expected, software companies have a similar behavior because of the type of product+service they sell. The wearables company and the biotech assume similar behaviors only when it comes to distribution, customer relationship and number and diversity of suppliers, again because of the type of products they sell.

Another interesting fact discovered during this study was that the BMC dimensions were routinely used by the interviewees whilst the supply chain dimensions where sometimes unknown or at least, not so familiar. Due to that fact and because of the evident connections between the business model and the supply chain that were ascertained throughout this study via the PMSC framework and the cross-referencing analysis, an

approach to supply chain design (Supply Chain Canvas) was suggested, using a similar visual tool to the BMC. The way both BMC and SCC can dynamically interact with each other and allow for an easy visualization of the dimensions allows for the companies to rapidly adapt to changes in their markets and their consumers' needs.

5.2 Limitations

This study, as any approach that intends to summarize reality and turn it into a theory or a model suffers from limitations.

Using a multiple-case study of five university spin-offs represents only 1/3 of the companies incubated in UPTEC in the healthcare sector. Although expanding these findings may have a negative effect on reliability due to generalizations, the dimensions explored under this study have been widely accepted as solid indicators that would turn the effect of scaling negligible in case of a study focused on a wider sample, including spin-offs from other universities and geographies.

The study focused on the actual situation of the companies. Although change was observed as a result of adaptation to market and suppliers' constraints, this was not taken into consideration and, therefore, produced a static view instead of a dynamic view that would deepen the analysis focused on change drivers.

The accuracy of the answers may also have been affected by the interviewees notion of reality. Although they all used the BMC as a common tool to design, sometimes they had difficulty expressing their point of views due to their limited business experience or limited time for the interview and some details may have been deliberately omitted due to being sensitive content for these companies. Such assumption was included in the interviews by choosing to keep the Cost structure and Revenue stream dimensions unexplored, yet they themselves are a limitation due to their omission.

Finally, natural limitations occur due to the extent of human behavior. Interpretation errors from both parties at the interviews, and bias induced by the interviewer may also

have contributed to additional imprecision. The validity of the coding process is also subjected to bias and may reduce accuracy.

Despite all the limitations outlined above, it is believed that this study has produced novel and valuable insights found on the relation between business models and supply chains, namely on university start-ups in the healthcare area.

5.3 Future research

This research process used a multiple-case study of five startups who were originally UP's spinoffs. Further research can be performed using a wider sample from different universities and geographies in the healthcare sector. Expanding the study to other sectors and to other types of start-ups rather than only university spin-offs may prove to be also relevant.

The approach used for this study was a "static" situation of the start-ups, much like a photography taken at any given moment – in this case, of their actual business model and supply chain. While this study used a qualitative analysis to compare the different companies, further research using qualitative or quantitative analysis along a timeline would provide a more dynamic outlook.

Another interesting research path would be to explore and compare business models and supply chains of mature companies and start-ups and evaluate how they remain competitive by dynamically adjusting to market change and how long does such change take to be effective.

This study was based in two scopes, business model and supply chain, trying to find the relation between them. Yet, each dimension explored under those scopes have their own relevancy and depth and therefore thorough research of each dimension and its variables represents an interesting opportunity for further analysis.

Finally, the multilevel point of view that intends to broaden the range of the Business Model Canvas philosophy to supply chain explored on this dissertation by means of the

Supply Chain Canvas, as well as to the environment life cycle and the social stakeholder referred in 4.3, among other dimensions that are part of a company, may represent an opportunity to design its entire roadmap in order to have the most complete tool to face the challenges of demanding and ever changing markets, while contributing for accountability and to the society's wellbeing.

Appendix A – Interview questionnaire

#	*Question*	*Dimensions*	*Keywords*
1	"Which are your company's types and groups of customers?"	Customer segments	Mass market, niche market, diversification
2	"What value or benefits does your company offer to customers?"	Value proposition	Newness, performance, customization, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility, convenience/usability
3	"Which channels does your company use to communicate, sell and distribute your products to companies?"	Channels	Own channels, partner channels, mixed
4	"Which are the most important resources your business model relies on?"	Key resources	Human, financial, physical and intellectual
5	"Which are the most important activities your company performs?"	Key activities	Production, supply-chain management, R&D, problem-solving, sales, platform/network
6	"Who are the most important partners your company's activities rely on?"	Key partners	Strategic alliance (non-competitors), strategic partnership (competitors), joint-venture, buyer-supplier relationship

#	Question	Dimensions	Keywords
7	"Which kind of relationship has been built with your customers?"	Customer relationships	Personal assistance, self-service/automated service, communities, co-creation
8	"In which way does your company differentiate in the market?"	Competitive differentiators	Design capability, design lead time, cost, quality, lead time, service level, reliability
9	"What are your company's products demand characteristics?"	Demand characteristics	Product life cycle, time window for delivery, volume, variety, variability
10	"What are your company's supply characteristics?"	Supply characteristics	Replenishment lead-times, availability, reliability of suppliers
11	"What is your company's sourcing strategy?"	Sourcing strategy	Single vs multiple, local vs global, criteria of selection
12	"What type of relationship have you established with companies in your supply chain?"	Supply chain relationships	Strategic partnerships, supply chain integration, information sharing
13	"What is your company's production environment strategy?"	Production environment	Make-to-order, make-to-stock or mixed type

Appendix B – Interview summary

Question no. 1	*"Which are your company's types and groups of customers?"*
	Dimension: Customer segments
	Keywords: Mass market, niche market, diversification
Case study A	Before* – "First we sold our products to Medical students but the payed app did not achieve great success." After* – "We modified our customer target and began to sell a product+service to medical training institutions"
Case study B	Before* – "Medical area", "Professional sports market" After* – "For personal use of the sports' enthusiast, mainly runners"
Case study C	"Hospitals, clinics and practices"
Case study D	"Public hospitals and regional health directorates", "Further expansion of the market due to demand in the private sector: private hospitals, clinics and practices. We're also negotiating with pharmaceutical companies"
Case study E	"Hospitals and labs with human microbiology testing", "we expect to expand to the veterinary and food sectors"

** Note: before and after refer to different stages of the companies due to change in their business models. Only later stages were considered in the analysis results.*

Question no. 2	*"What value or benefits does your company offer to customers?"*
	Key dimensions: Value proposition
	Keywords: Newness, performance, customization, "getting the job done", design, brand/status, price, cost reduction, risk reduction, accessibility, convenience/usability
Case study A	"Improve students' examination skills", "Institution provides a better training to students and certifies their skills", "Remote learning", "sale of certification to practitioners", "one out of five practitioners don't know how to correctly perform the exam"
Case study B	"Unique and valuable data acquisition of the body's movement"
Case study C	"Our software allows day-to-day work to be done faster", "Data visualization allows for its management and promotes research"
Case study D	"Big technical-scientific knowledge allows us to have a very advanced approach", "Our connection with UP allows for the reliance of our partners because we deal with sensitive information", "Market leaders", "No competitors in public tenders"
Case study E	"Decrease diagnostic time", "Save in prescription drugs costs", "Avoid [bacterial] dissemination", "Decrease antibiotics resistance"

Question no. 3	*"Which channels does your company use to communicate, sell and distribute your products to companies?"*
	Dimension: Channels
	Keywords: Own channels, partner channels, mixed
Case study A	Before* – Appstore After* – "We began with an order from UP's Faculty of Medicine.", "…investment in marketing", "contact network and word of mouth".
Case study B	Before* – "Medical equipment distributors and partnerships" After* – "Amazon", "Own webstore"
Case study C	"Opinion-makers networks [in their own clinical] specialties", "Spread the word", "Email and AdWords publicity"
Case study D	"Contact network", "Public financed tenders with us being the sole bidders creates a reputation in the market"
Case study E	"Scientific exhibitions", "Microbiology conferences", "Via partner companies"

** Note: before and after refer to different stages of the companies due to change in their business models. Only later stages were considered in the analysis results.*

Question no. 4	*"Which are the most important resources your business model relies on?"*
	Dimension: Key resources
	Keywords: Human, financial, physical and intellectual
Case study A	"Know-how of the team", "Contact network"
Case study B	"Industrial design skills", "Disruptive technology"
Case study C	"Our computer programmers", "Network of opinion-makers who are, at the same time, our clients and our "marketeers""
Case study D	"Technicall skills", "Knowledge of the directive's requests because partner participated in EU regulatory commission", "Contact network", "Open-source software"
Case study E	"Experience and know-how"

Question no. 5	*"Which are the most important activities your company performs?"*
	Dimension: Key activities
	Keywords: Production, supply-chain management, R&D, problem-solving, sales, platform/network
Case study A	"Sales", "Data sampling", "Database maintenance"
Case study B	"Control out-sourced production", "Creating and enhancing our software platform", "Prototyping", "Sales management through our webshop"
Case study C	"Build the product according to its [the clients'] inputs", "follow-up meetings to tune the product"
Case study D	"Customizing and testing of open-source software [according to] our clients' needs", "Software optimization due to proximity with the customer [and] knowledge of European regulations"
Case study E	"R&D and certification activities"

Question no. 6	*"Who are the most important partners your company's activities rely on?"*
	Dimension: Key partners
	Keywords: Strategic alliance (non-competitors), strategic partnership (competitors), joint-venture, buyer-supplier relationship
Case study A	"The clients themselves, we collect the samples from their patients"
Case study B	"IEEE", "INESC TEC", "our suppliers"
Case study C	"Opinion-makers"
Case study D	"UP", "contact network"
Case study E	"Regulatory and certification partners", "Industrial partners"

Question no. 7	*"Which kind of relationship has been built with your customers?"*
	Dimension: Customer relationship
	Keywords: Personal assistance, self-service/automated service, communities, co-creation
Case study A	"Very close relationship, treating each other by the first name" because "we had to tune the product and spent a lot of time together"
Case study B	"Our products are sold via Amazon or our web-shop"
Case study C	"We've built a clients' base among our network of contacts", "Got to be close due to meetings to include their inputs in the product"
Case study D	"Over the time we've developed a close relation because we sit down with the clients to evaluate their needs"
Case study E	"We sell our products via our suppliers or via network of contacts"

Question no. 8	*"In which way does your company differentiate in the market?"*
	Dimension: Competitive differentiators
	Key words: Design capability, design lead time, cost, quality, lead time, service level, reliability
Case study A	"Uniqueness and technology of the product", "Competitive cost" with "initial acquisition plus maintenance fees", "customization", "continuous development"
Case study B	"Development of our industrial design skills for a short development time", "Disruptive technology", "lower acquisition cost", "flexible design", "features are well beyond competition"
Case study C	"Customization according to the customer's needs, "Follow-up meetings"
Case study D	"Technical skills", "Customization based on open-source software", "Constant updates"
Case study E	"Bigger cost-effectiveness and lower running costs" in a product "with equal outputs as current systems"

Question no. 9	*"What are your company's products demand characteristics?"*
	Dimension: Demand characteristics
	Key words: Product life cycle, time window for delivery, volume, variety, variability
Case study A	"Customization requires sampling per type of diagnostic", "depending on clients request, we can have a system ready from within eight to eighteen months"
Case study B	"Hardware lasts for two years", "Orders through Amazon are always fulfilled within a week" and it's "a little shorter on our site", "5000 units per batch", "six sizes of inner soles and three colors of the device"
Case study C	"We offer a complete new version every two year", "usually the system is ready in two or three months, we could deliver faster but the final version takes a little longer due to customization"
Case study D	"Life cycle of one year before a new version comes to market", "Delivery takes four to five months because of particular adaptations to the multiple software our clients use"
Case study E	"We expect a long life cycle because it's a one time buy system", "Almost immediate delivery", "Customer can purchase additional modules to test for other bacteria"

Question no. 10	*"What are your company's supply characteristics?"*
	Dimension: Supply characteristics
	Key words: Replenishment lead-times, availability, reliability of suppliers
Case study A	"Almost immediately", "initial problems with individual practitioners' techniques and position of patients led us to reformulate the data sampling process"
Case study B	"Production takes four months because our suppliers have high demand for their products ", "Our products use readily available smartphone components"
Case study C	"Our updates are made every three months"
Case study D	"Updates every four months"
Case study E	"When product is ready for market after certification [we can supply] on demand", "Our suppliers have immediate stock"

Question no. 11	*"What is your company's sourcing strategy?"*
	Dimension: Sourcing strategy
	Key words: Single vs multiple, local vs global, criteria of selection
Case study A	"Database is built on clients' requests on their location", "data sampling is unique to the client"
Case study B	Before* – "procurement of electronics" from various sources globally, "assembling ourselves" After* – "process control", "quality checks", "global supply chain", "production in China due to specific capabilities that are lost in Europe", "assembly and testing in Europe"
Case study C	"Our software is designed for the clients' requests and programmed by our team"
Case study D	"Based on open-source software, we create a product 100% made by us in Portugal based on the clients' needs"
Case study E	"We have privileged relations with several suppliers in Europe"

** Note: before and after refer to different stages of the companies due to change in their business models. Only later stages were considered in the analysis results.*

Question no. 12	*"What type of relationship have you established with companies in your supply chain?"*
	Dimension: Supply chain relationships
	Key words: Strategic partnerships, supply chain integration, information sharing
Case study A	"Very close because, as referred, we collect data samples from our clients' patients"
Case study B	"A relationship built on trust, some of our suppliers even financed our production"
Case study C	"Close relationship with our customers", "Close relation with the opinion-makers"
Case study D	"Due to dealing with sensitive data, we have a close relationship with our clients"
Case study E	"We have partnerships with our long supplying [hospital laboratory machinery and consumables] partners"

Question no. 13 *"What is your company's production environment strategy?"*

	Dimension: Production environment
	Key words: Make-to-order, make-to-stock or mixed type
Case study A	"make-to-order", "basic app is adapted"
Case study B	"mixed type, we have stock items and combinations are made by according to our clients' order and then shipped from our partners' warehouse"
Case study C	"make-to-order, we cannot talk about "software stock" because of customization"
Case study D	"make-to-order although using readily available open-source software code"
Case study E	"make-to-order according to customers' needs when product is certified"

Appendix C – Node list

Name	Sources	References	Created On
Channels	0	0	06/09/2017 12:25
Mixed	2	4	05/09/2017 18:53
Own Channels	5	11	05/09/2017 18:53
Partner Channels	2	2	05/09/2017 18:53
Competitive Differentiators	0	0	06/09/2017 12:30
Cost	3	3	05/09/2017 19:00
Design capability	4	6	05/09/2017 19:00
Design lead time	1	1	05/09/2017 19:00
Reliability	1	1	05/09/2017 19:01
Service level	5	6	05/09/2017 19:00
Customer Relationship	0	0	06/09/2017 12:29
Co-creation	2	2	05/09/2017 18:59
Personal Assistance	3	3	05/09/2017 18:58
Self-Service;Automated Service	2	2	05/09/2017 18:59
Customer Segments	0	0	06/09/2017 12:22
Mass Market	1	1	05/09/2017 18:44
Niche Market	4	6	05/09/2017 18:43

Demand characteristics	0	0	06/09/2017 12:32
Product life cycle	4	4	05/09/2017 19:01
Time window for delivery	5	6	05/09/2017 19:01
Variability	1	1	05/09/2017 19:02
Variety	3	3	05/09/2017 19:02
Volume	1	1	05/09/2017 19:02
Key Activities	0	0	06/09/2017 12:26
Platform-Network	4	4	05/09/2017 18:56
Problem-Solving	1	1	05/09/2017 18:55
Production	4	4	05/09/2017 18:55
R&D	2	2	05/09/2017 18:55
Sales	2	2	05/09/2017 18:56
Supply-chain management	1	1	05/09/2017 18:55
Key Partners	0	0	06/09/2017 12:27
Buyer-Supplier Relationship	5	5	05/09/2017 18:57
Joint-Venture	1	1	05/09/2017 18:57
Strategic alliance	3	3	05/09/2017 18:56
Strategic Partnerships	2	2	05/09/2017 19:05

Key Resources		0	0	06/09/2017 12:25
Human		5	5	05/09/2017 18:53
Intellectual		5	7	05/09/2017 18:54
Production Environment		0	0	06/09/2017 12:35
Make-to-order		5	6	05/09/2017 19:06
Mixed Type		1	1	06/09/2017 12:36
Sourcing Strategy		0	0	06/09/2017 12:33
Local vs Global		5	9	05/09/2017 19:05
Single vs Multiple		5	6	05/09/2017 19:05
Supply Chain Relationships		0	0	06/09/2017 12:34
Information sharing		2	2	05/09/2017 19:06
Supply chain integration		3	3	05/09/2017 19:06
Supply characteristics		0	0	06/09/2017 12:32
Reliability of suppliers		3	3	05/09/2017 19:04
Replenishment lead-times		5	5	05/09/2017 19:03

Value proposition	0	0	06/09/2017 12:22
Accessibility	1	1	05/09/2017 18:52
Brand-Status	1	2	05/09/2017 18:50
Convenience-Usability	3	4	05/09/2017 18:52
Cost Reduction	1	1	05/09/2017 18:50
Getting the job done	2	2	05/09/2017 18:49
Newness	1	1	05/09/2017 18:48
Performance	5	5	05/09/2017 18:48
Risk Reduction	3	4	05/09/2017 18:51

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